Kalamazoo River Area 5

DRAFT

Recon II Data Evaluation and SRI Phase I Sampling Design



March 13, 2018

Georgia-Pacific

Objectives

- Describe Recon II data collection and evaluation
- Share current CSM
- Present SRI Phase I Sampling design

Agenda

- Summary of Area 5 Progress to Date
- Impounded Lake Sediment
  - Recon I & II Data Evaluation
  - Phase I Sample Design
- Channelized Flow Sediment
  - Recon II Data Evaluation
  - Phase I Sample Design
- Floodplain Soils
  - Recon II Data Evaluation
- MNR LOE Sampling

Area 5 Sampling Events

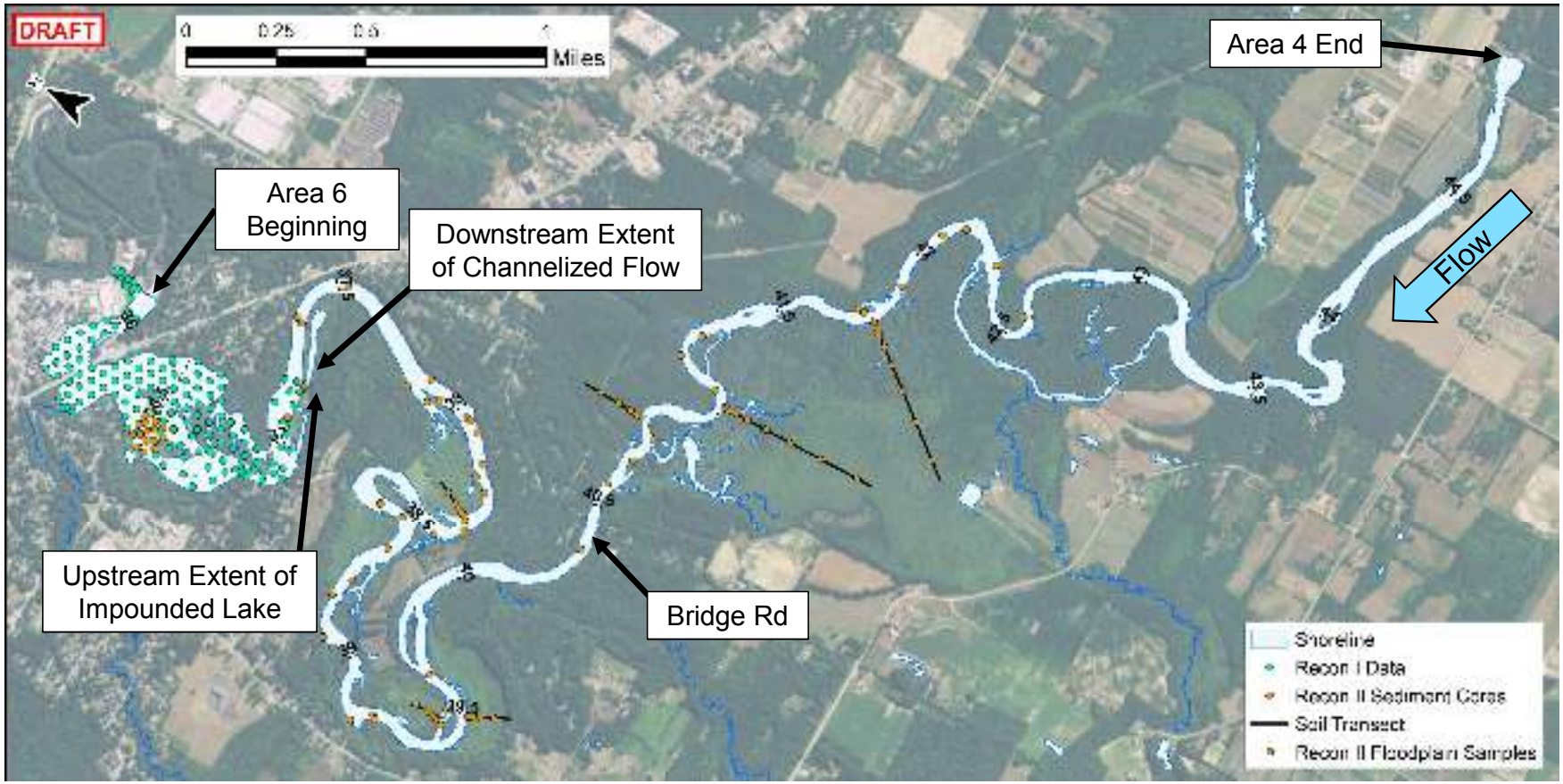
Event	Purpose of Sampling	Timeframe	
Recon I	► Pilot test for gradation in sediment ► Begin CSM ► Estimate study boundary	Spring 2017	✓
Recon II	► Advance CSM for remainder of Area 5 ► Identify bedform/grain size groups and sampling density for Phase I ► Refine proposed study boundary	Fall 2017	✓
Phase I SRI Sampling	► Sample to support SRI, ASTM, & FS ► Includes nature and extent, MNR LOEs, SWAC, terrestrial risk, alternatives development, etc. ► Data may serve dual purpose of supporting nature and extent/FS and RD, if well planned	Summer 2018	
Phase II SRI Sampling	► Fill remaining data gaps as necessary	Summer 2019	

Approach for Area 5 SRI

- Different Conditions
  - Impounded lake, consistent water levels maintained at dam, floodplains not formerly impounded
  - Potential for MNR

- Study approach is different than upstream Areas
  - Starting with high resolution topobathy data and hydrodynamic modeling
  - Map bedforms
  - Hydrodynamic model early to scope Recon II floodplain sampling
  - Use of rapid field lab techniques to aid the investigation
  - Limited PCB sampling in Recon II to guide statistically based, unbiased Phase I SRI Sampling design
  - MNR more fully evaluated

Area 5 Definitions

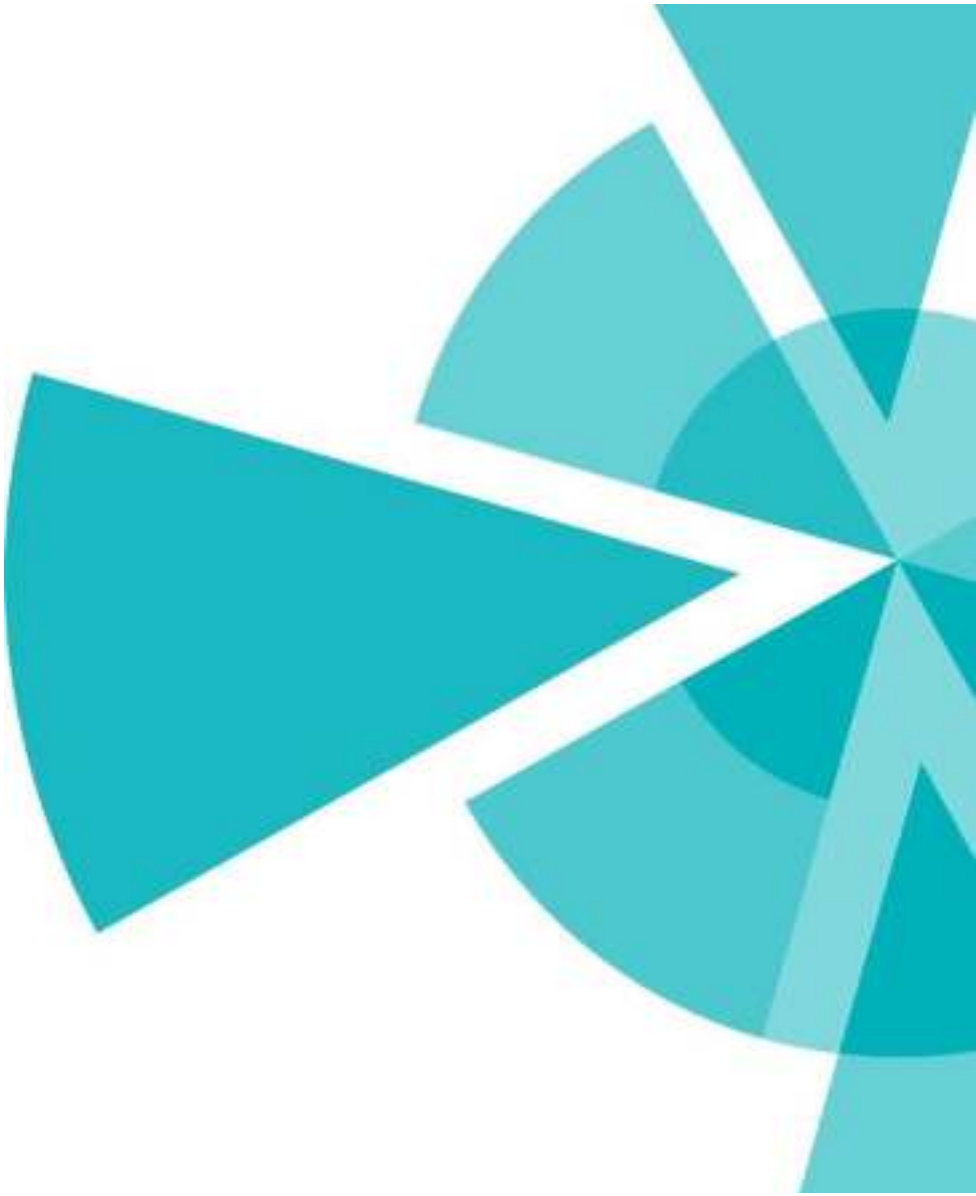


Impounded Lake Sediment

DQOs

Recon I & II Data Evaluation

Phase I SRI Sampling Design



Phase I SRI Impounded Lake Sediment

- Decision Statements (DQOs)
  - Implement an unbiased investigation strategy with a random origin that is defensible and reproducible and provides a robust dataset for statistical evaluation.
  - Implement the investigation to generally define the vertical and horizontal extent of PCBs in sediment. Data gaps and refinement will be performed in a Phase II SRI sample collection.
  - Estimate surface weighted average PCB concentrations (SWACs) in sediment and perform an uncertainty analysis (Phase I and II).
  - Identify preliminary remedial areas at the resolution needed to support a feasibility study (Phase I and II) .

Phase I SRI Impounded Lake Sediment

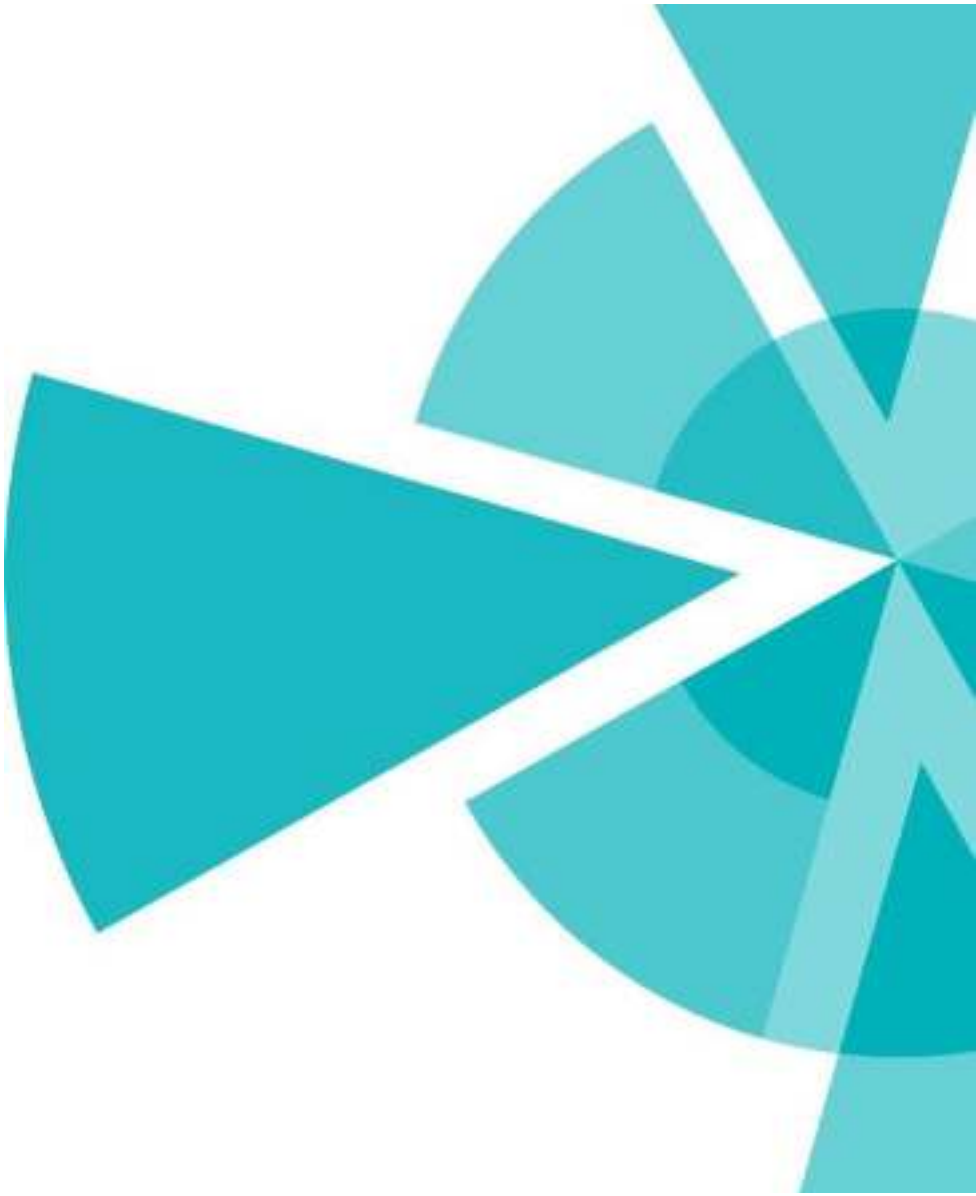
- Decision Statements (DQOs)
  - Collect data to support preliminary human health and ecological risk assessments (Phase I and II).
  - Collect data to refine hydrodynamic model (velocity measurements and additional water level measurements)
  - Identify areas where additional sampling is needed to support risk assessment and feasibility study evaluations in a Phase II event.

Impounded Lake Sediment

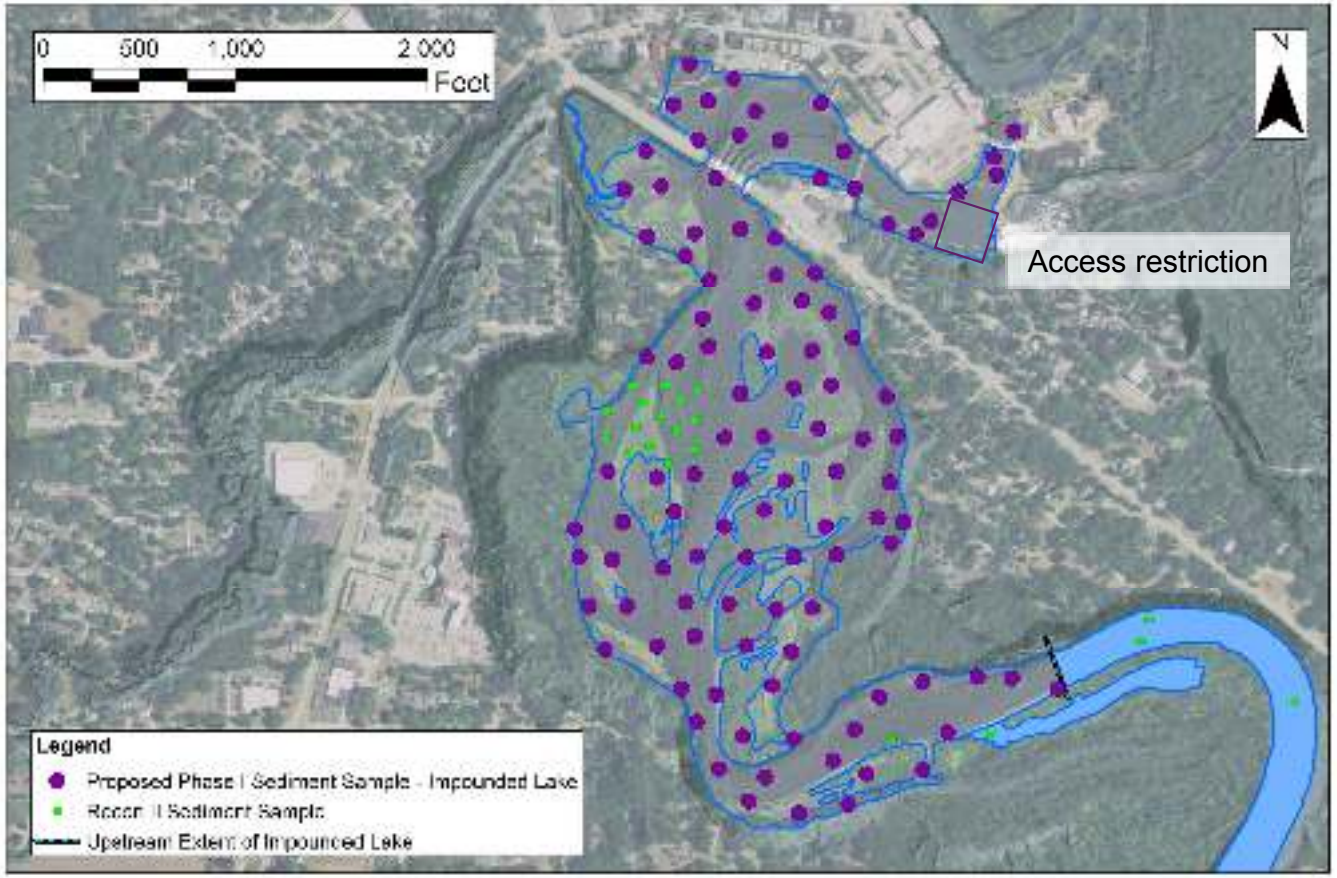
Preview of Phase I SRI Sampling Map

Explanation of Design

- **Review of Recon II Results**
  - **Vertical Texture**
  - **PCB Data**
- **Selection of Grid Spacing**



Phase I Sampling Design for Impounded Lake



- Random origin triangular grid with randomization at each location
- 105 locations (new)
- 250 ft average spacing

Impounded Lake

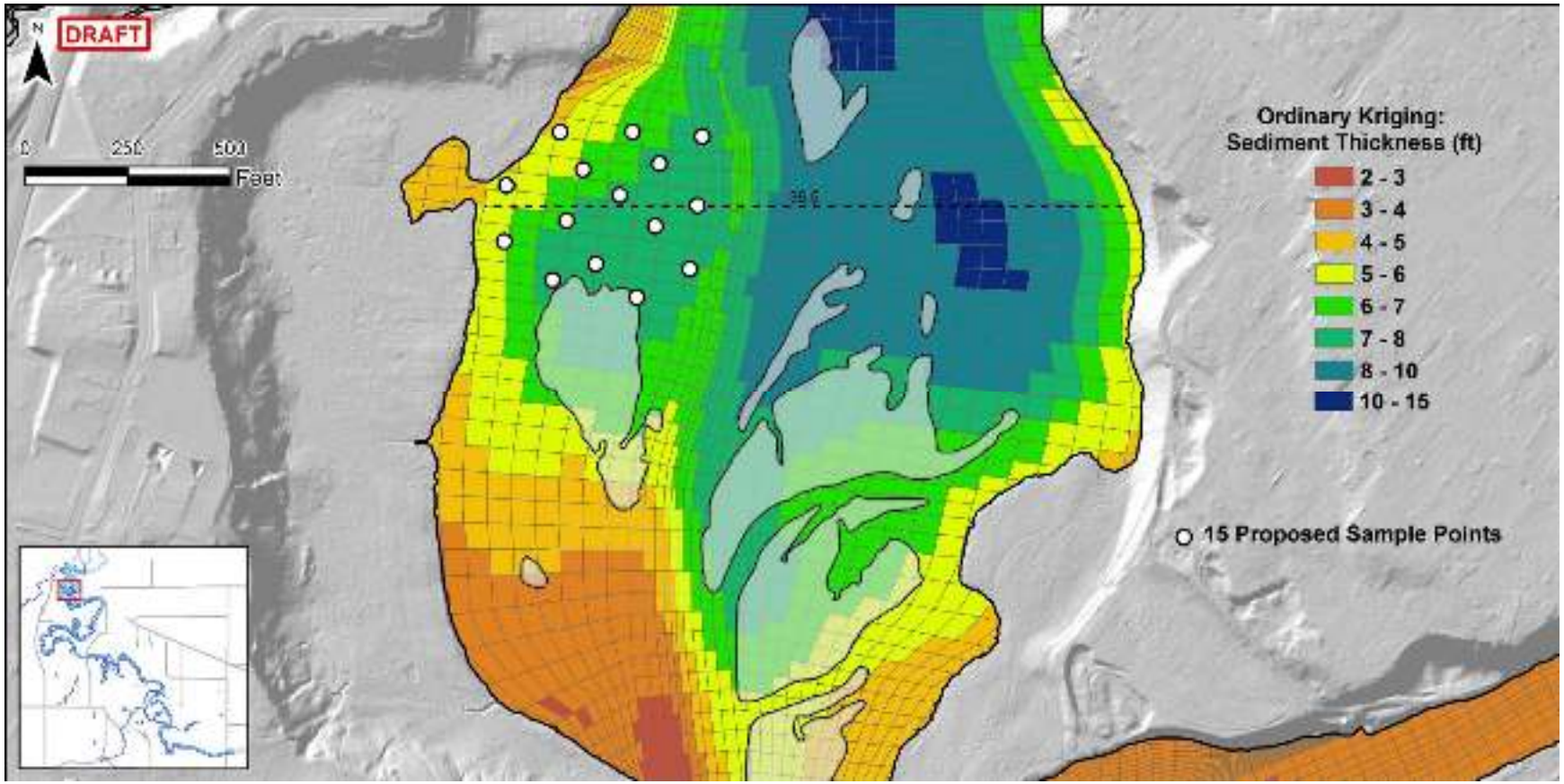
Recon II Activities:

- 15 sediment cores for PCB lab analysis, mini-grid densely spaced (~50 to 100 ft apart) to refusal depth (~8 ft)
  - PCB concentrations for variography, identify vertical extent of PCBs
  - SedImaging performed where mixed textures were encountered to assess vertical profile

Anticipated Phase I SRI Sediment Sampling Plan – Impoundment (most downstream 1 mile)

- Gridded sampling to develop geostatistical model for PCBs
  - Uniform horizontal spacing based on variography (generally more dense than Channelized Flow)
  - Vertical extent to bottom of soft sediment

Recon II Sample Layout for Impounded Lake

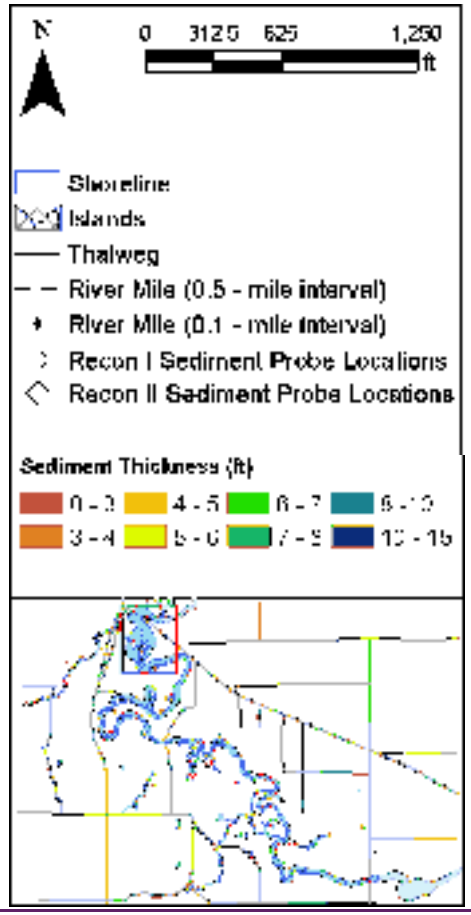


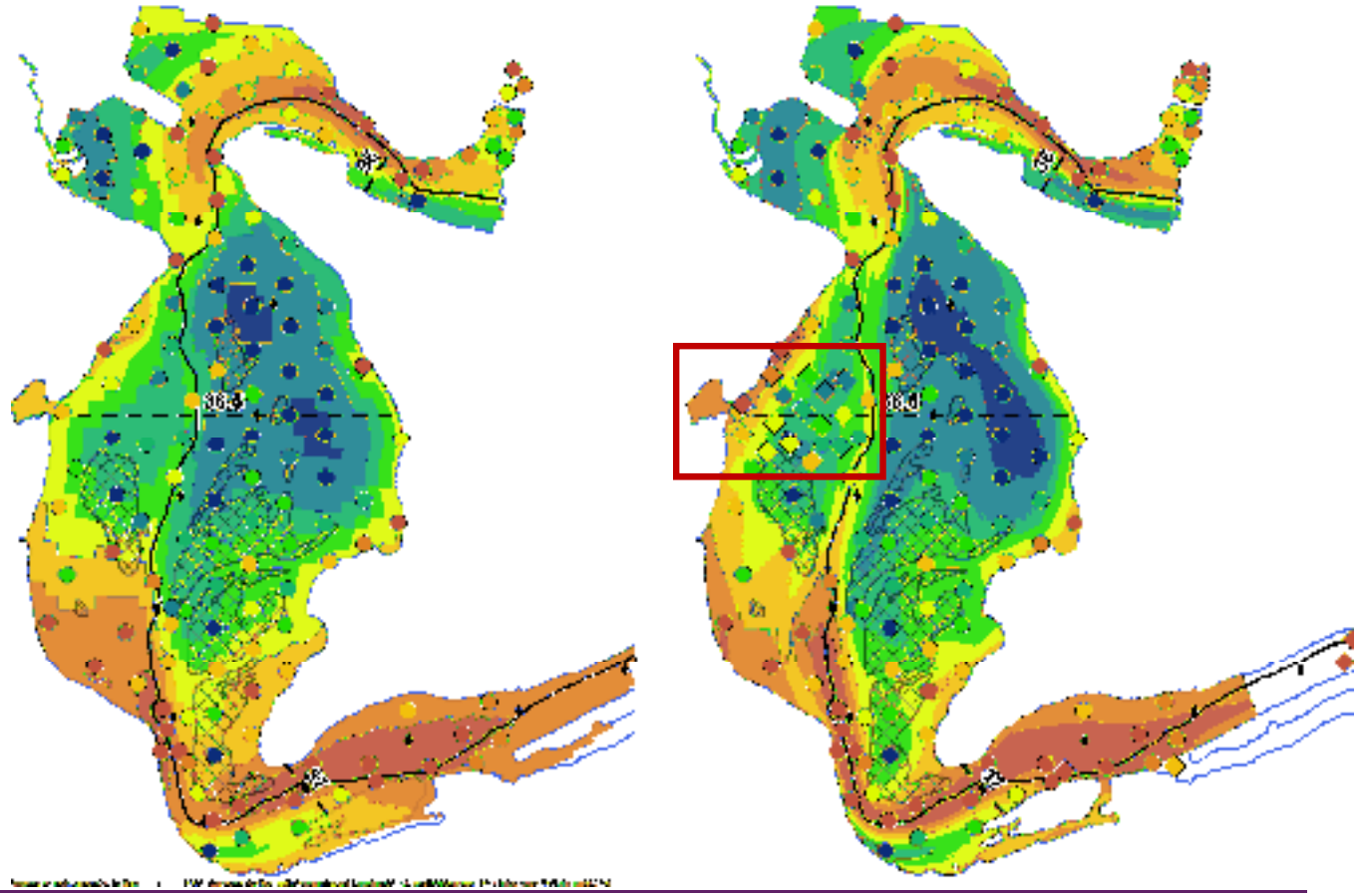
Results of Recon II – Impounded Lake Sediment

Recon II data evaluation shows:

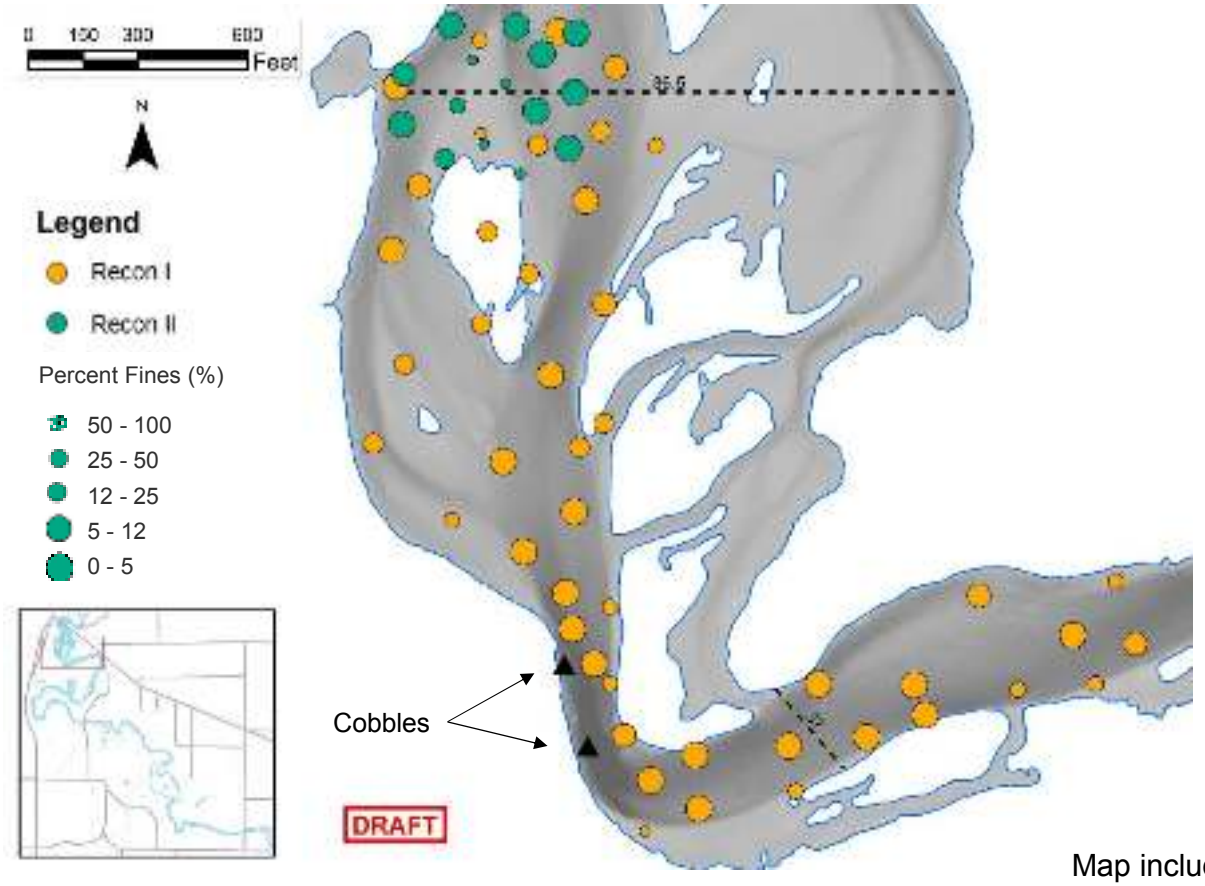
- Sediment thickness consistent with Recon I
- Surface gradation consistent with Recon I
- Gradation heterogeneous both horizontally and vertically
- Median PCB concentrations less than 1 mg/kg
  - Maximum concentration 41.6 mg/kg at Interval 3
  - Interval 1 Mean = 0.24 mg/kg, Median = 0.10 mg/kg
  - Interval 2 Mean = 1.09 mg/kg, Median = 0.25 mg/kg

Updated Sediment Thickness





Surface Gradation



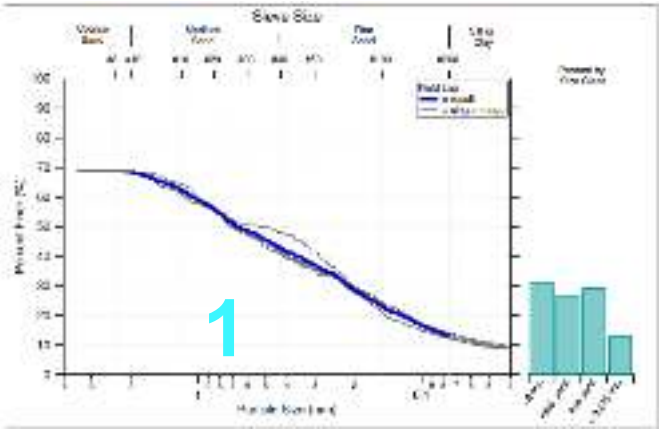
Map includes 5 estimated values

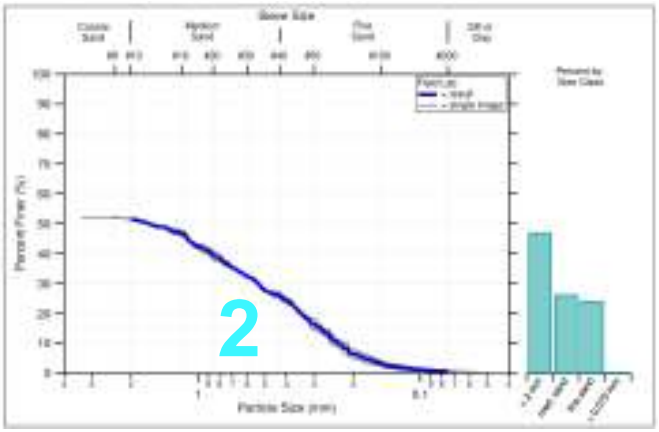
USCS Classification

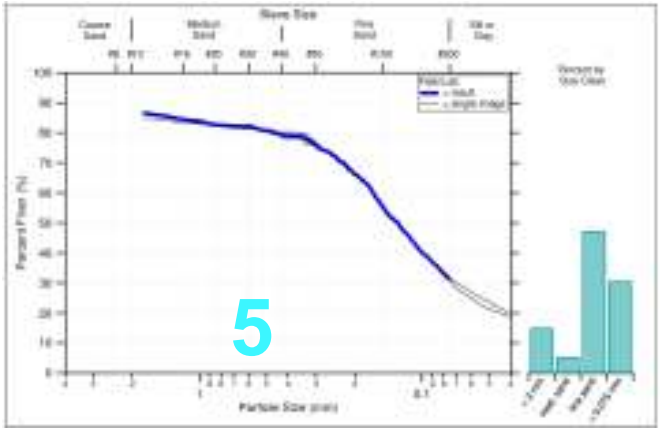
(more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)		
		GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)		
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)		
		SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)		
		SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures

FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

SED-049

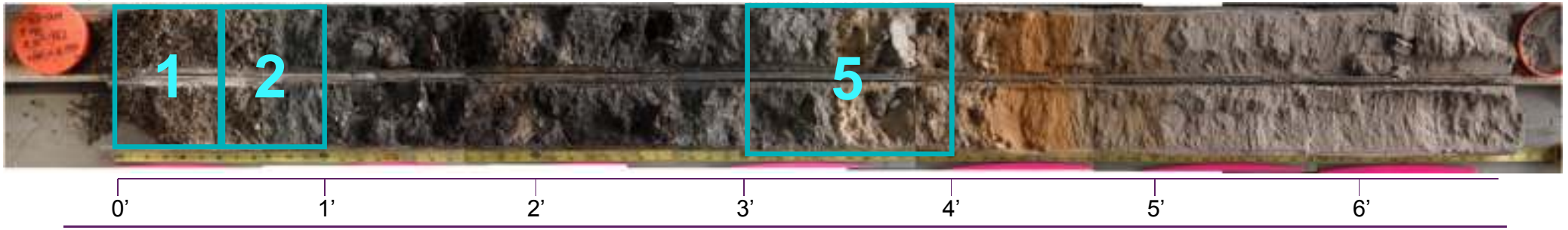




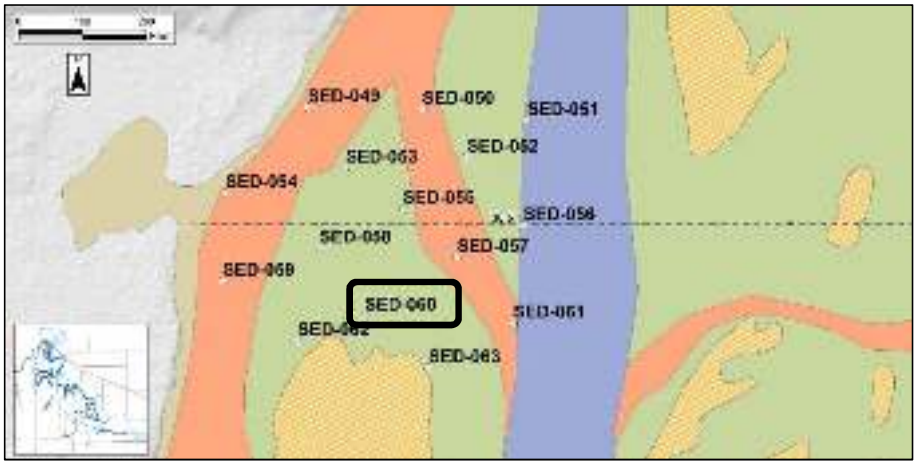


Top

Bottom



SED-060



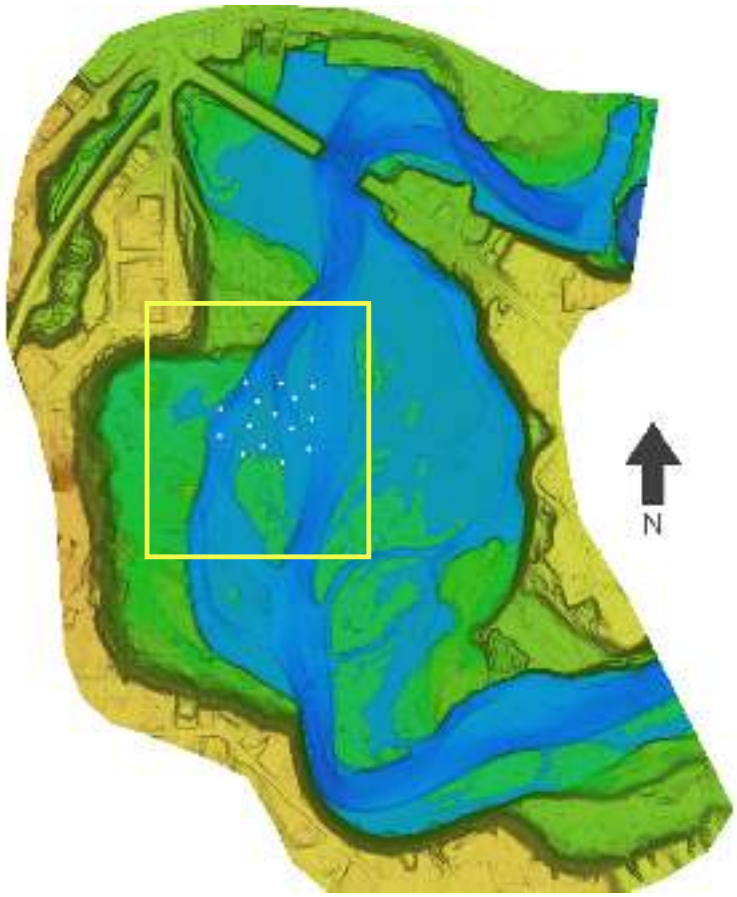
Bedform	Mouth Bar	
Soil Classification	Silt, above clay, above fine sand, above clay	
Sediment Thickness	6.0 ft	
PCB Concentration	Int 1:	0.42 mg/kg
	Int 2:	0.72 mg/kg
	Int 3:	8.50 mg/kg
	Int 4:	34.60 mg/kg
	Int 5:	4.00 mg/kg
	Int 6:	0.065 UJ mg/kg

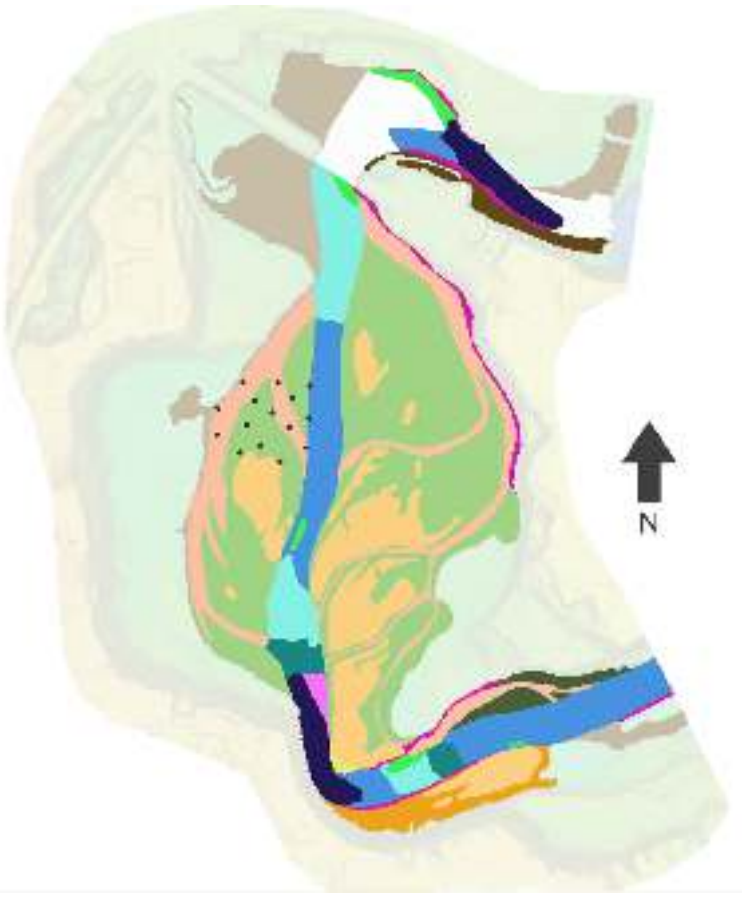
Top

Bottom

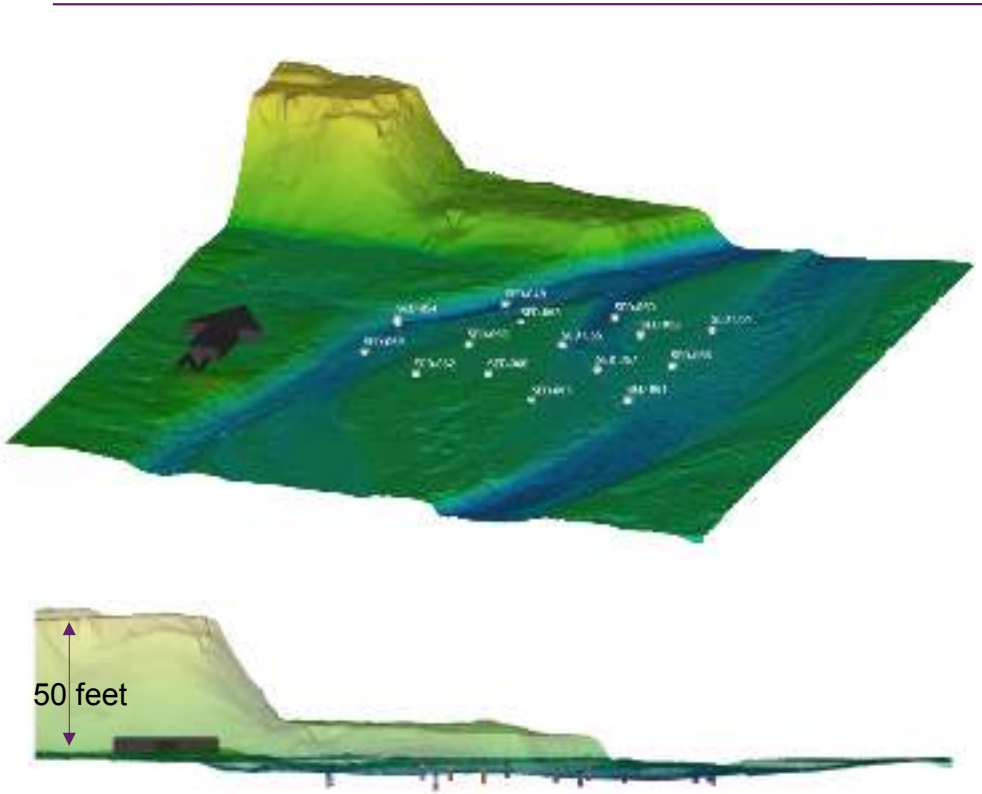
0’ 1’ 2’ 3’ 4’ 5’ 6’

Vertical Texture Consistency

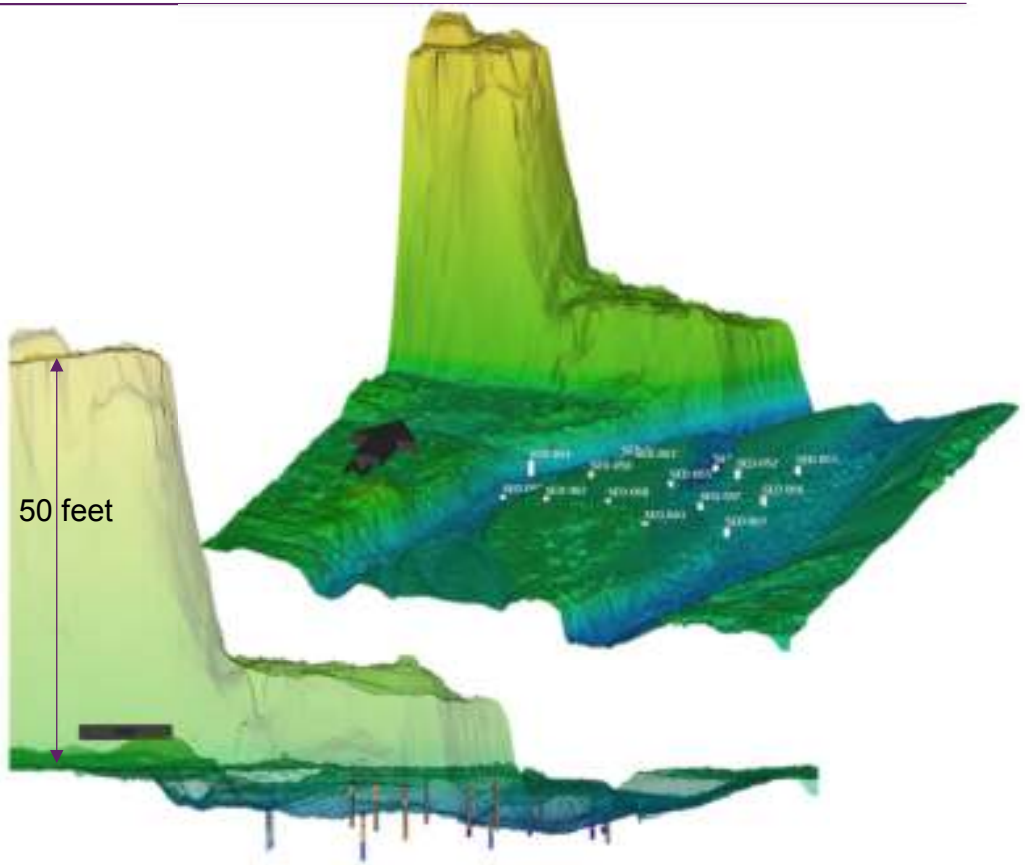




Vertical Texture Consistency

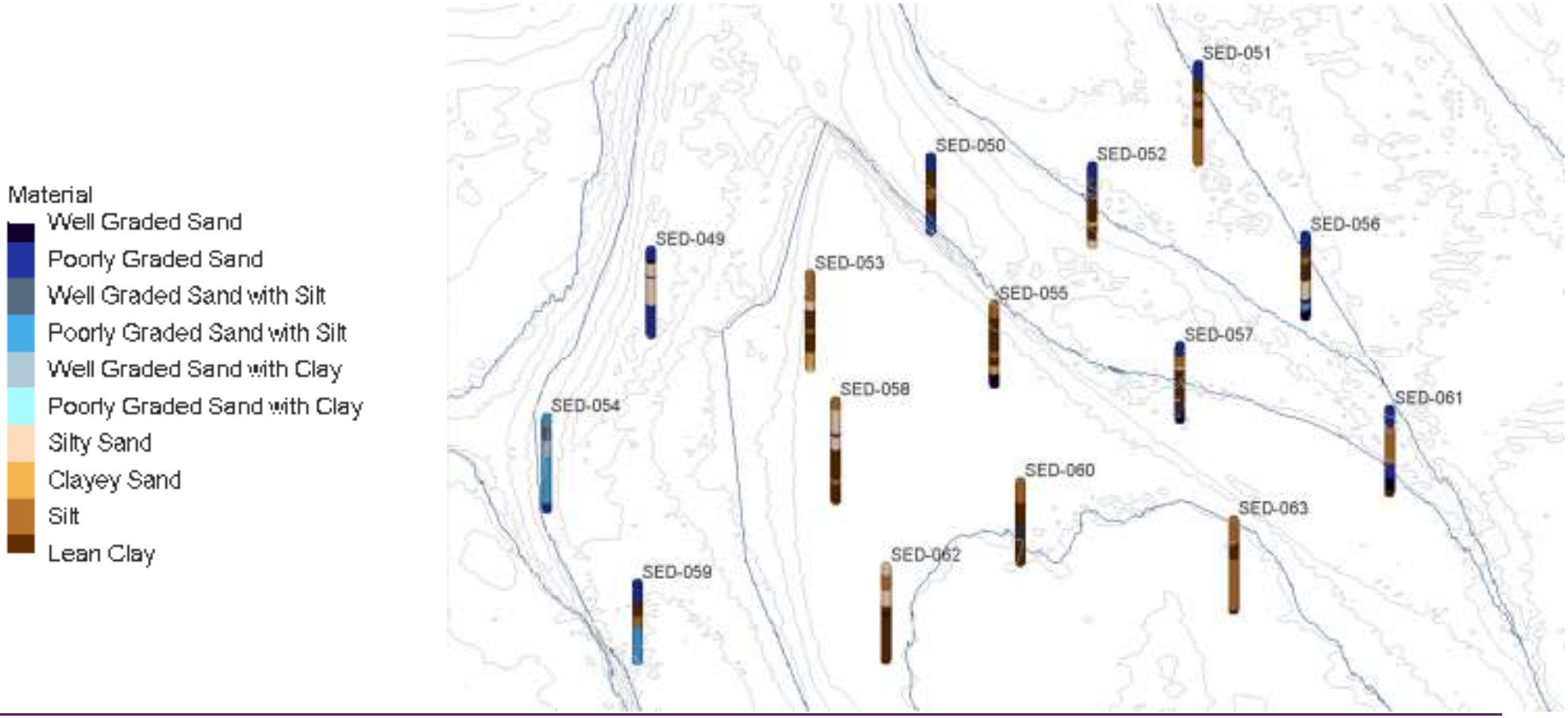


3x vertical exaggeration

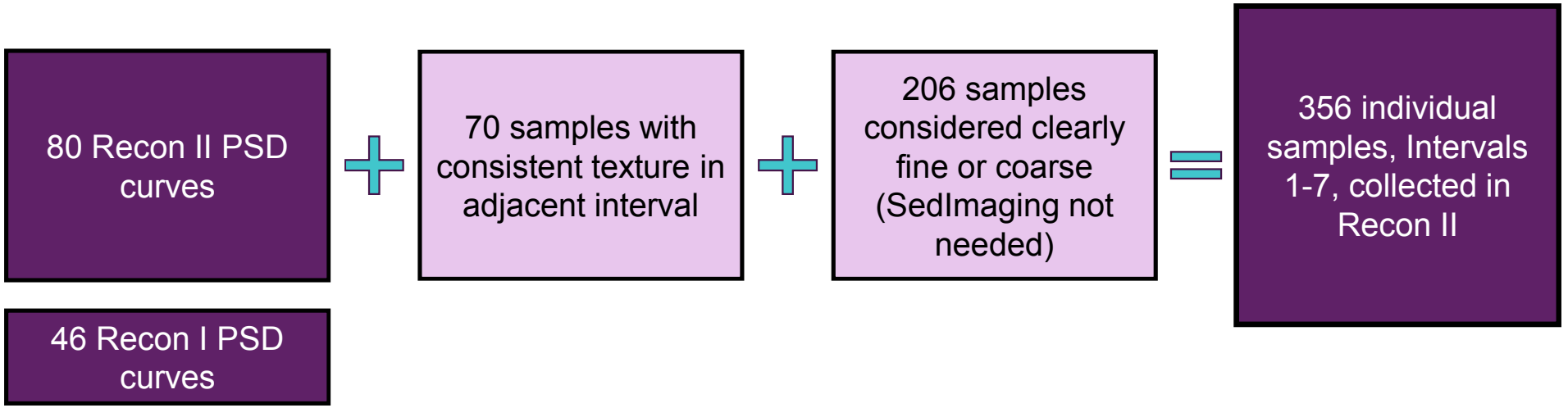


10x vertical exaggeration

Vertical Texture Consistency

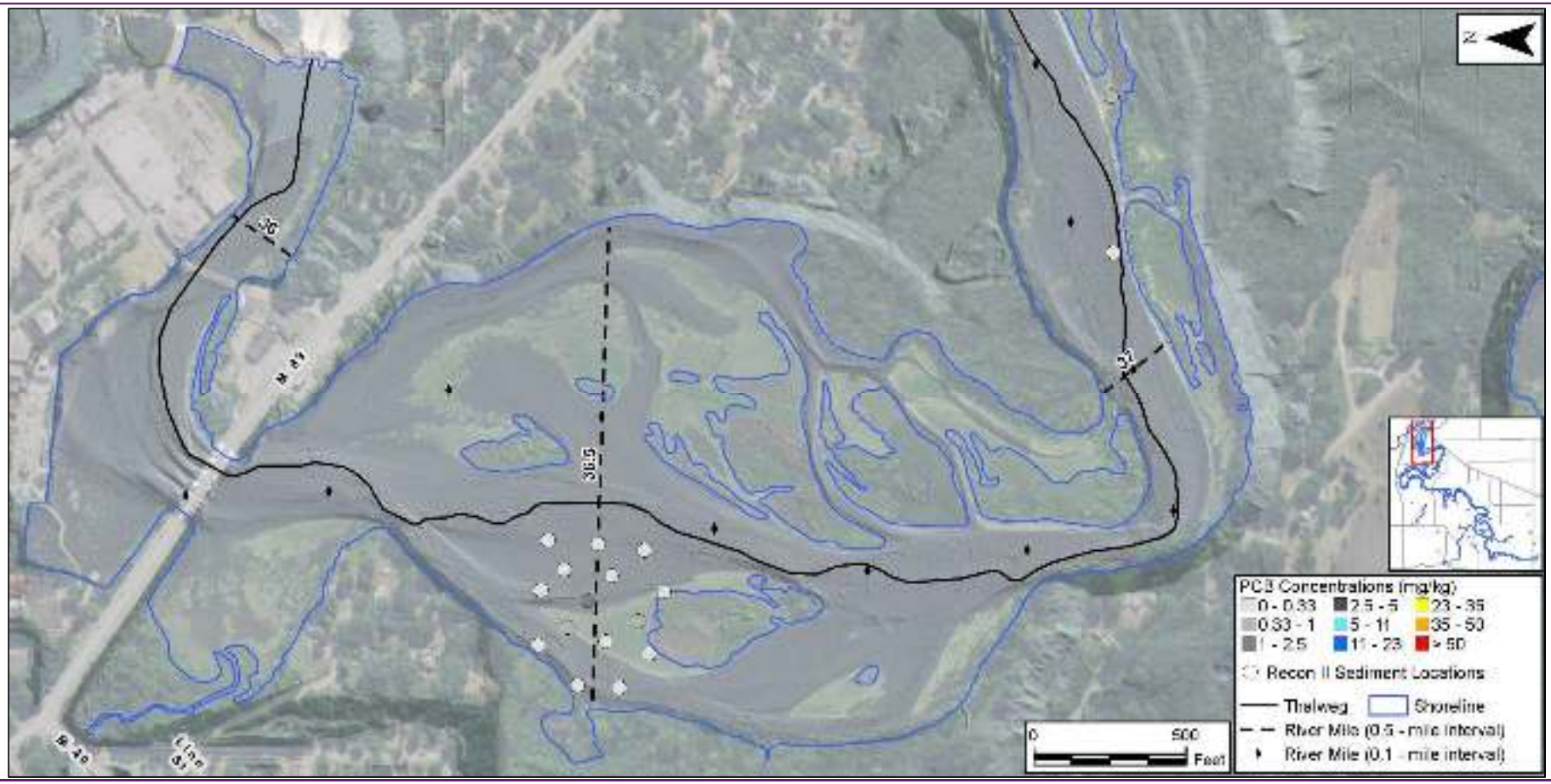


Approximating Gradation Data: Intervals 1-7

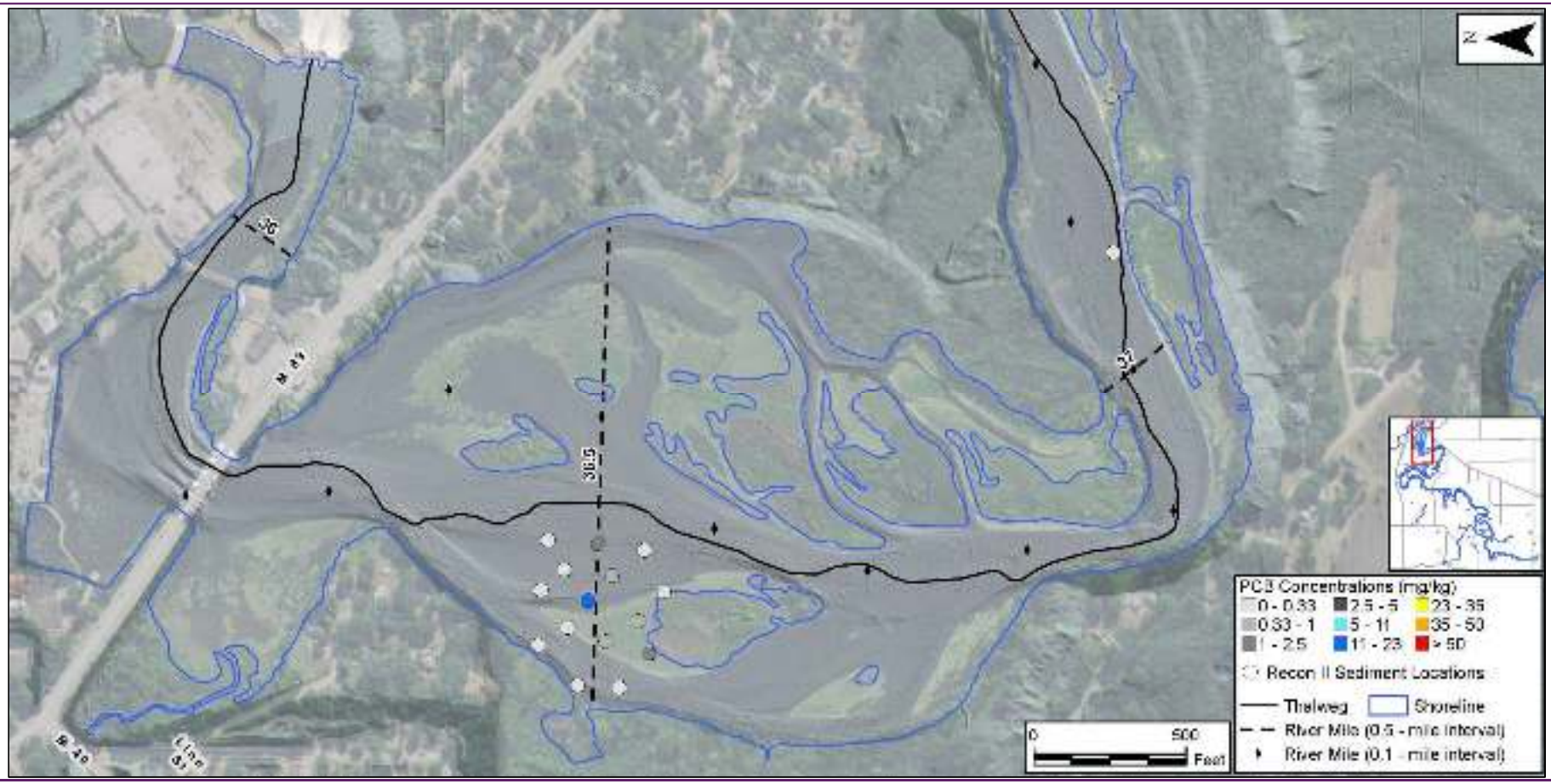


206 samples approximated USCS classifications using field logs

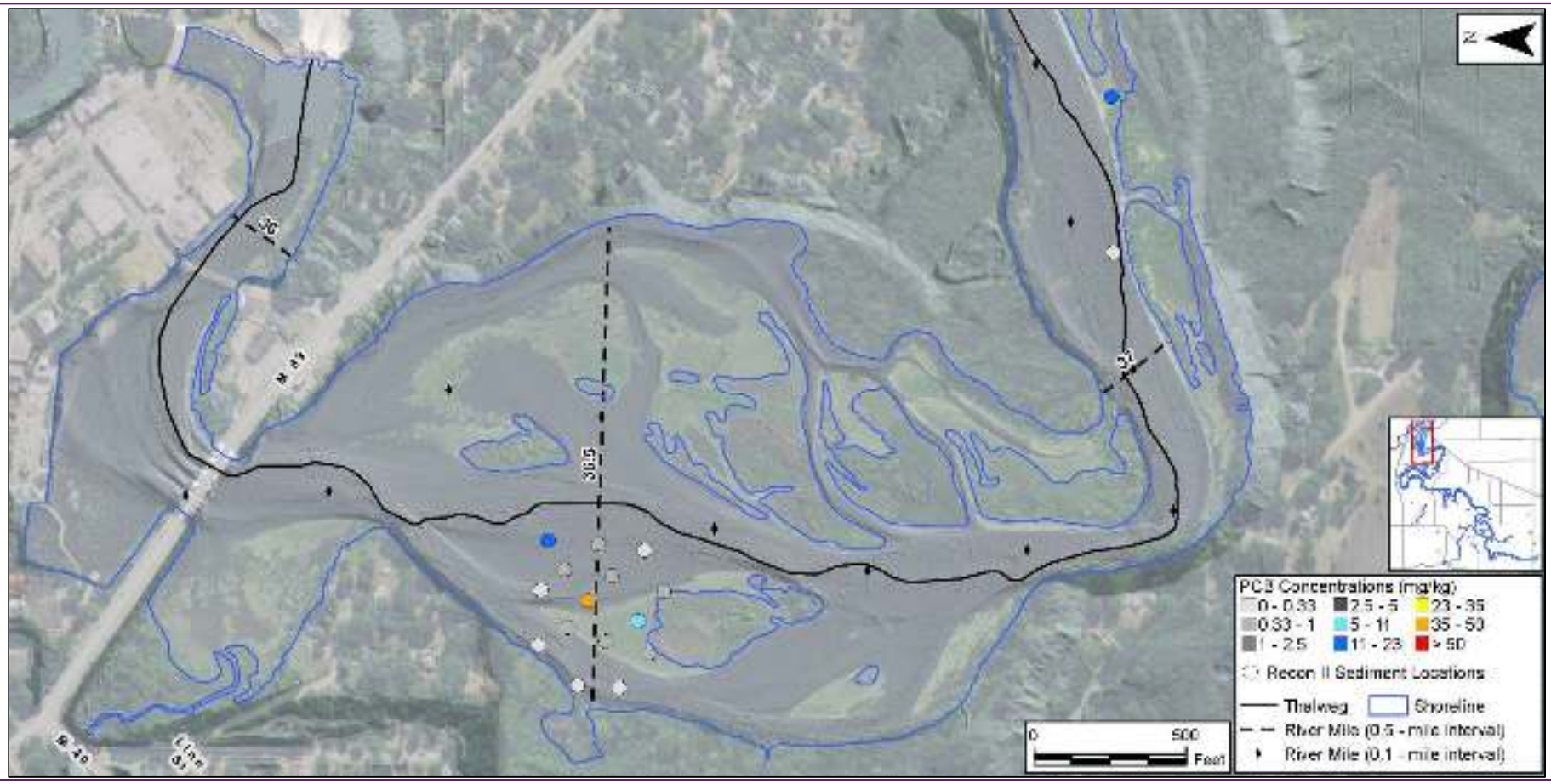
Recon II PCB Results – Interval 1



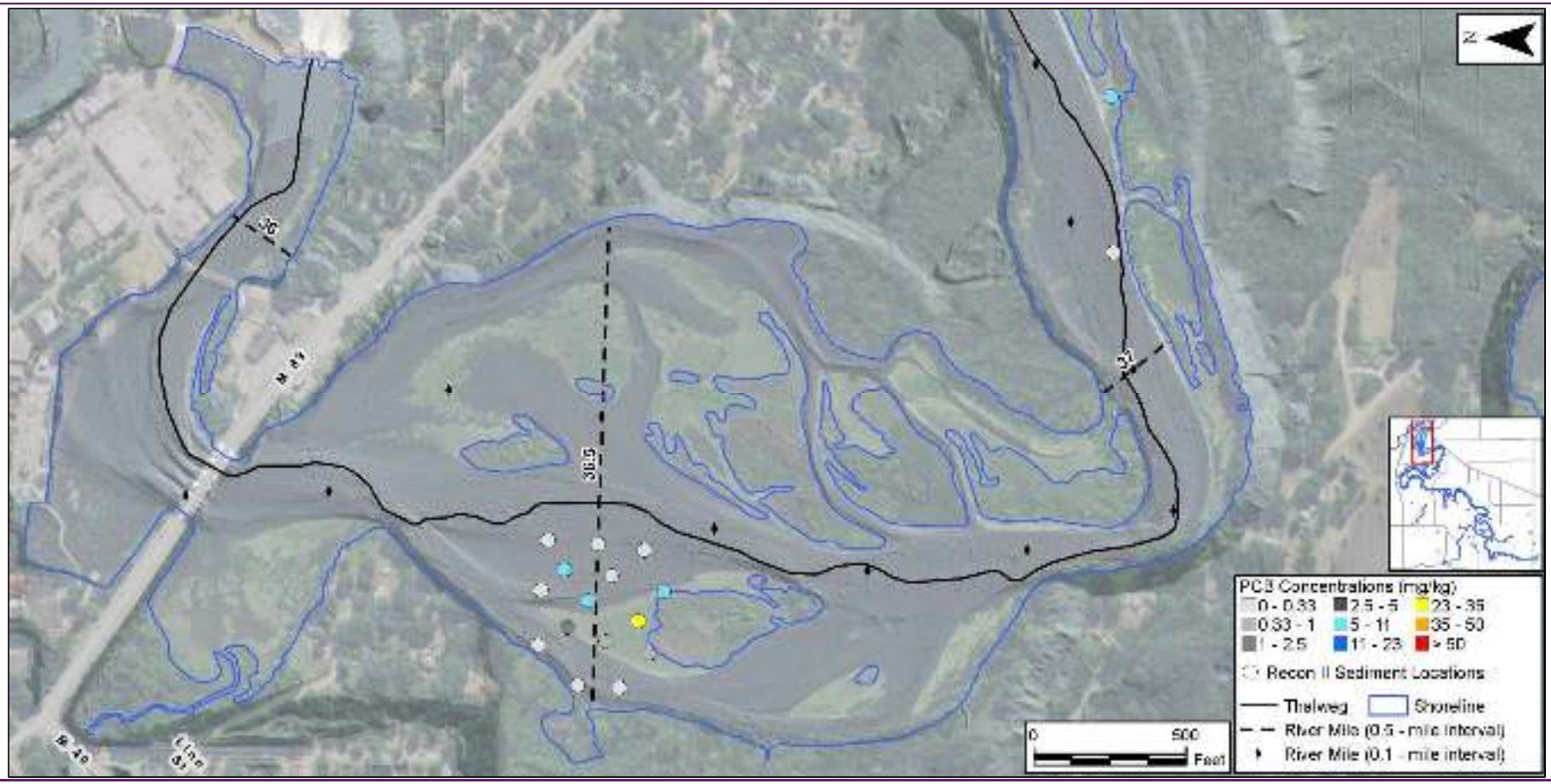
Recon II PCB Results – Interval 2



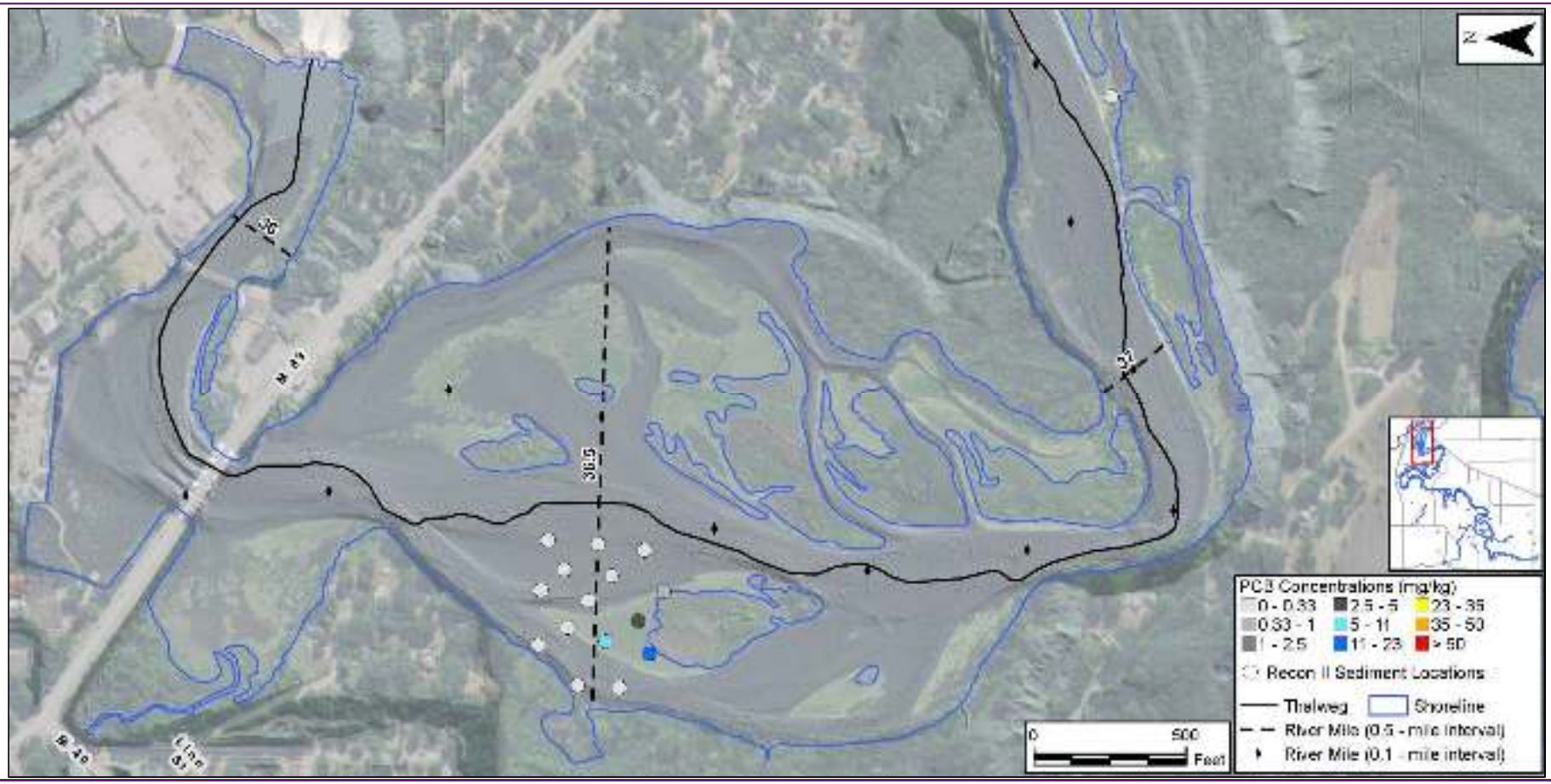
Recon II PCB Results – Interval 3



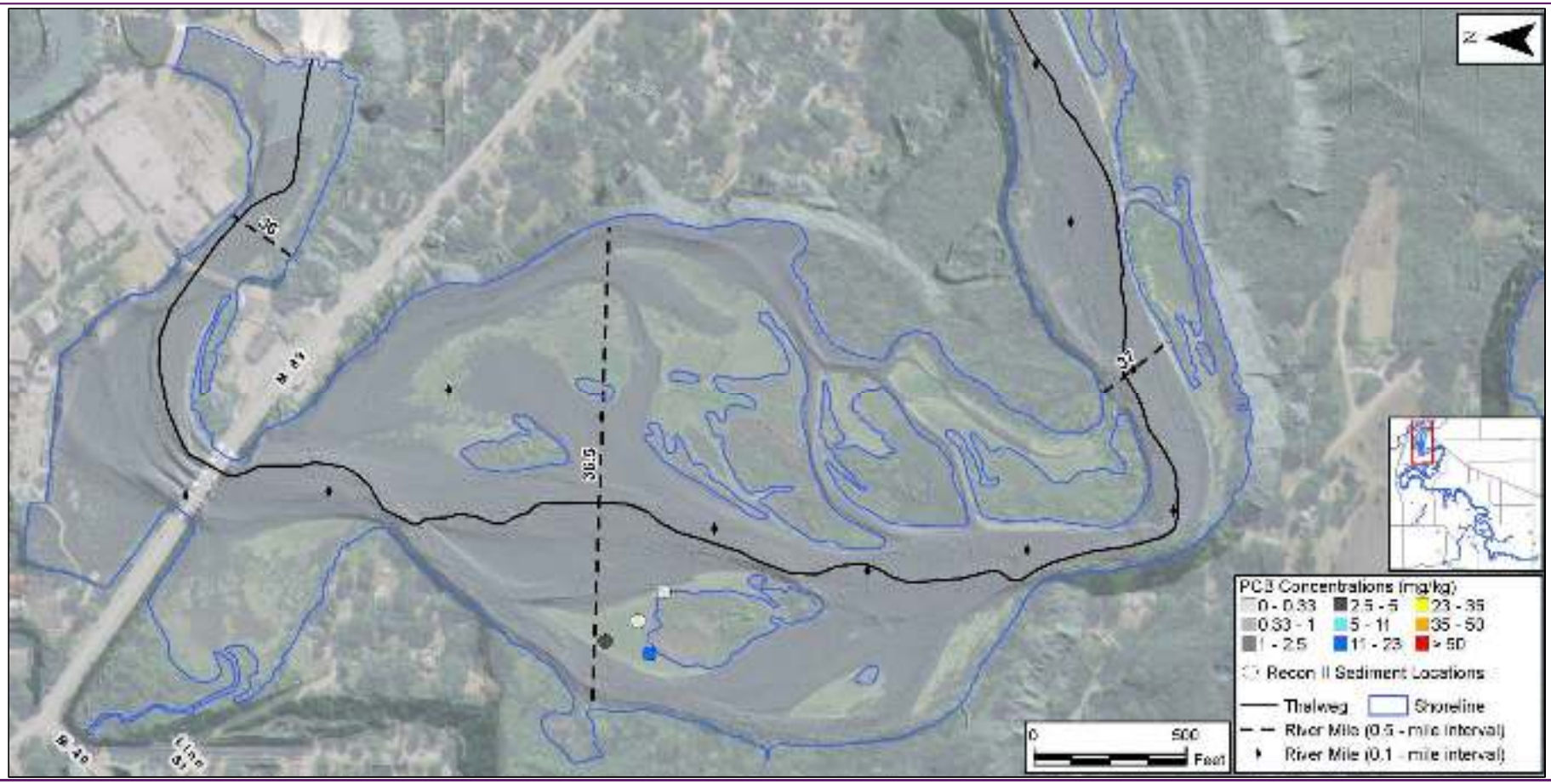
Recon II PCB Results – Interval 4



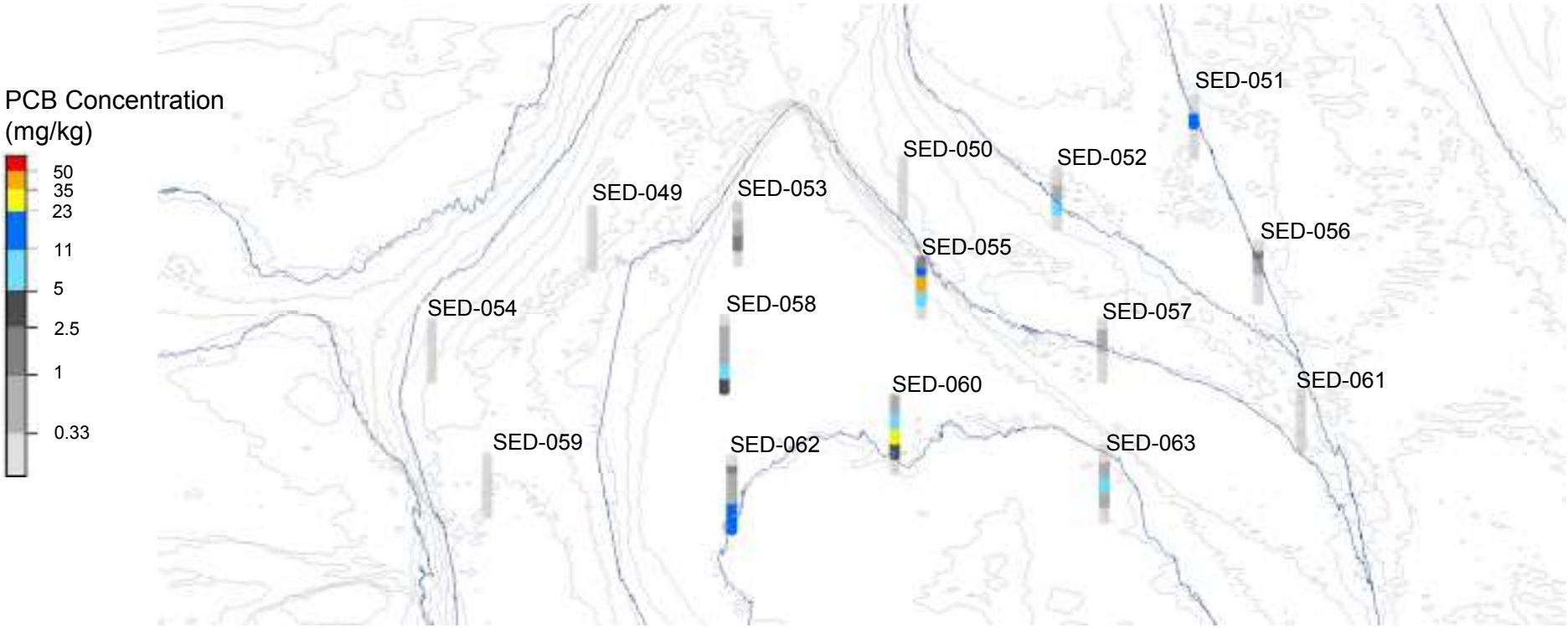
Recon II PCB Results – Interval 5



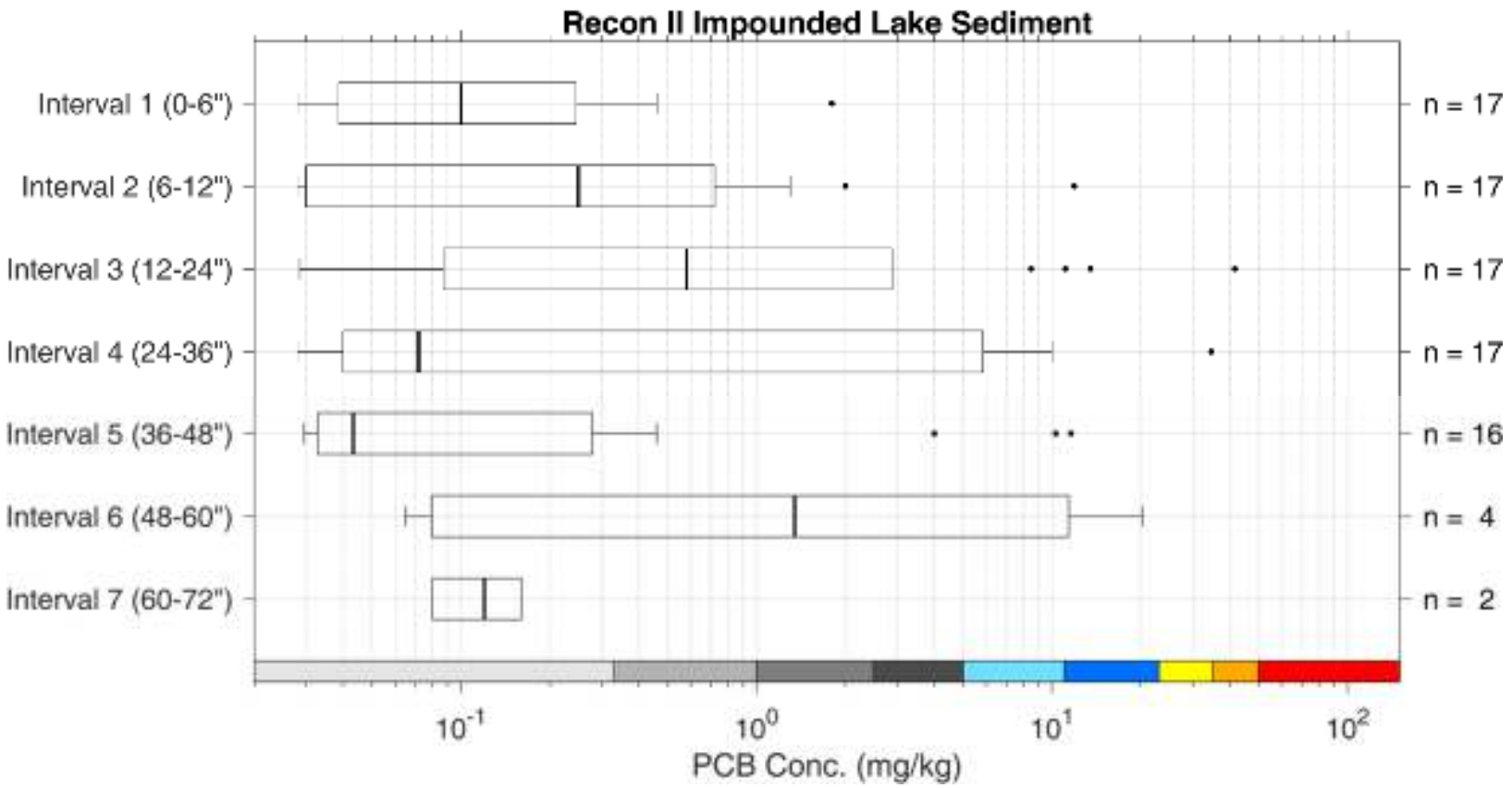
Recon II PCB Results – Interval 6



Recon II PCB Concentrations in Impounded Lake

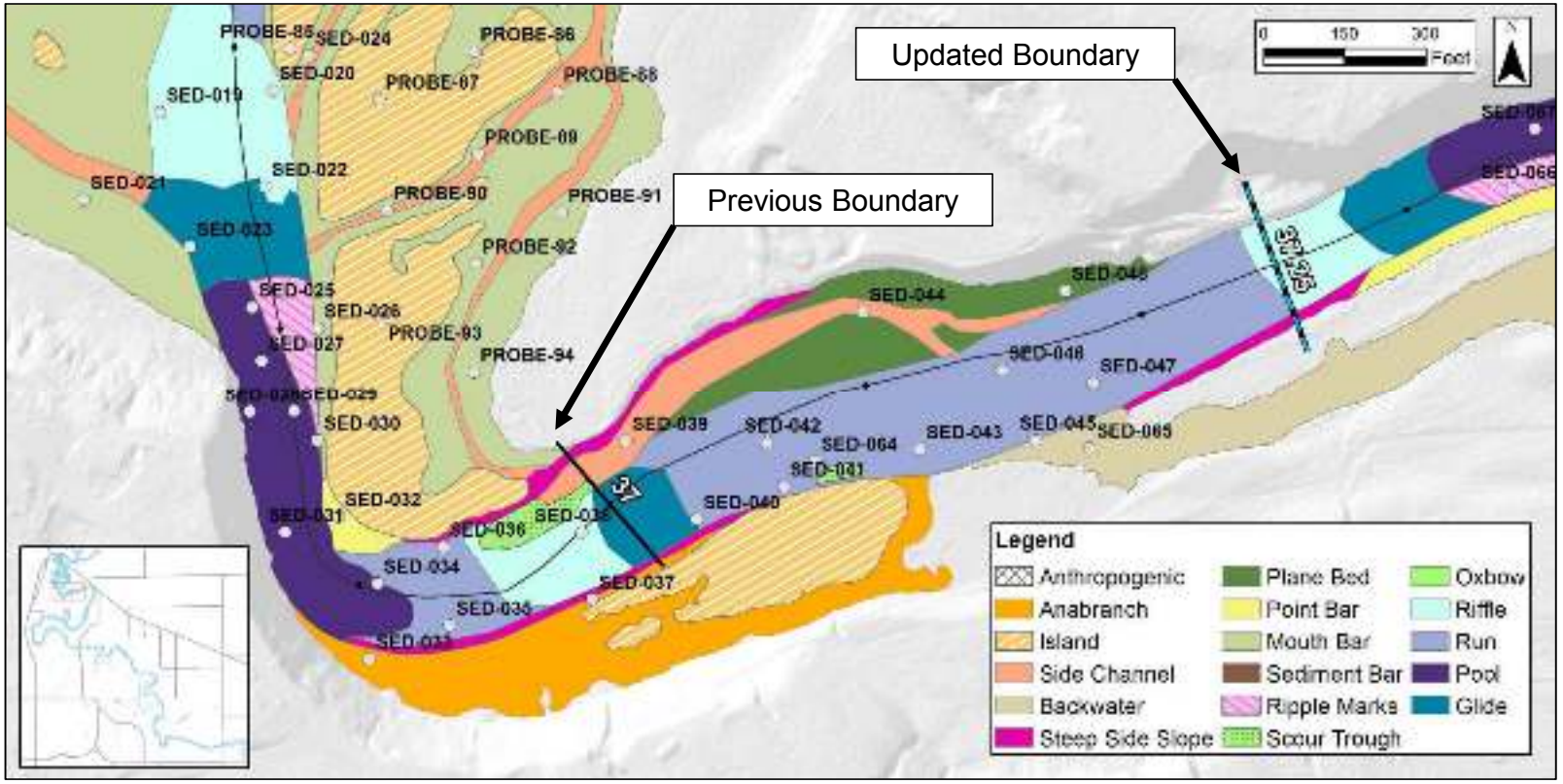


Recon II PCB Distributions by Depth



Redefining Upstream Extent of Impounded Lake

- Impounded Lake and Channelized Flow not separated by a hard physical boundary



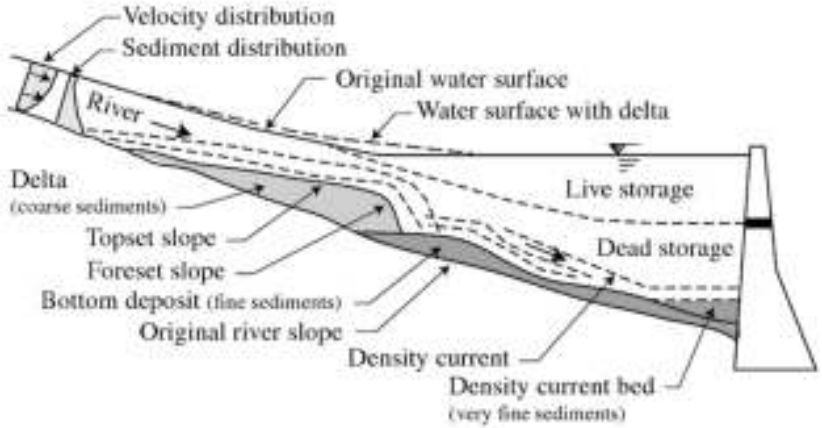
Redefining Upstream Extent of Impounded Lake

- Samples in transition zone tend to be finer compared to samples in same bedform upstream

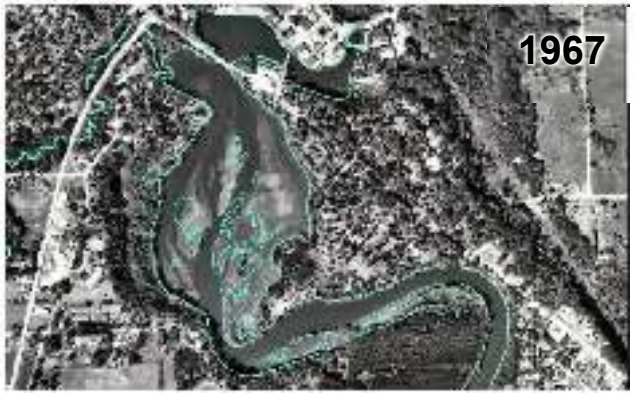
	Sample	Event	Bedform	Hydrodynamic Model			Sediment Thickness (ft)	% Fines	% Fine Sand	% Medium Sand	% Coarse
				Water Depth (ft)	Shear Stress (N/m2)	Velocity (ft/s)					
	SED-084	Recon II	Run	9.7	2.8	3.3	0.3	0.9	16.7	25	57.4
	SED-090	Recon II	Run	10.1	3.3	3.6	1.1	0	16.7	48.8	34.5
	SED-096	Recon II	Run	13.2	2.7	3.4	0.3	1.7	14.8	29.4	54.1
↑	SED-104	Recon II	Run	8.5	6.3	3.9	1	1.8	17.1	22.6	58.3
Upstream	SED-108	Recon II	Run	7.6	4.8	3.2	0.7	3.8	91.7	4.5	0
Downstream	SED-040	Recon I	Run	6.7	2.3	2.8	5.3	0.6	86.9	12.3	0.2
↓	SED-041	Recon I	Run	9.3	2	2.8	2.6	1.8	85.1	13	0.2
	SED-042	Recon I	Run	6.4	3	3.2	2.5	0.5	56.7	39.8	3
	SED-043	Recon I	Run	9.1	1.8	2.6	1	33	55.6	9.9	1.5
	SED-046	Recon I	Run	7.3	2.6	3	2.1	2.9	32.6	62.2	2.2
	SED-047	Recon I	Run	7.9	2.4	3	3.1	10.1	75.4	14.3	0.2
	SED-064	Recon II	Run	8.6	2.7	3.2	0.9	5	72.1	22.2	0.7

Preliminary Area 5 Conceptual Site Model – Impounded Lake

- Coarse sediments deposited at upstream extent of impoundment
- Fine sediments deposited downstream adjacent to main flow
- Bedload deposited further downstream over time
- Grain size variable with depth

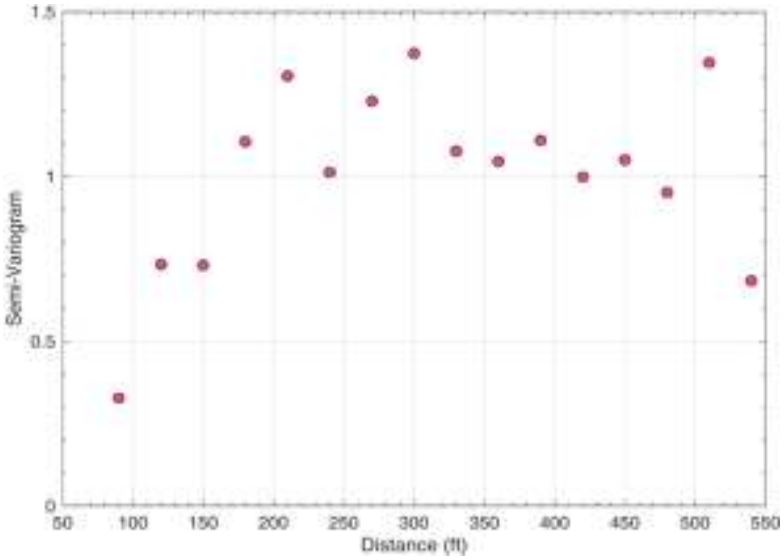


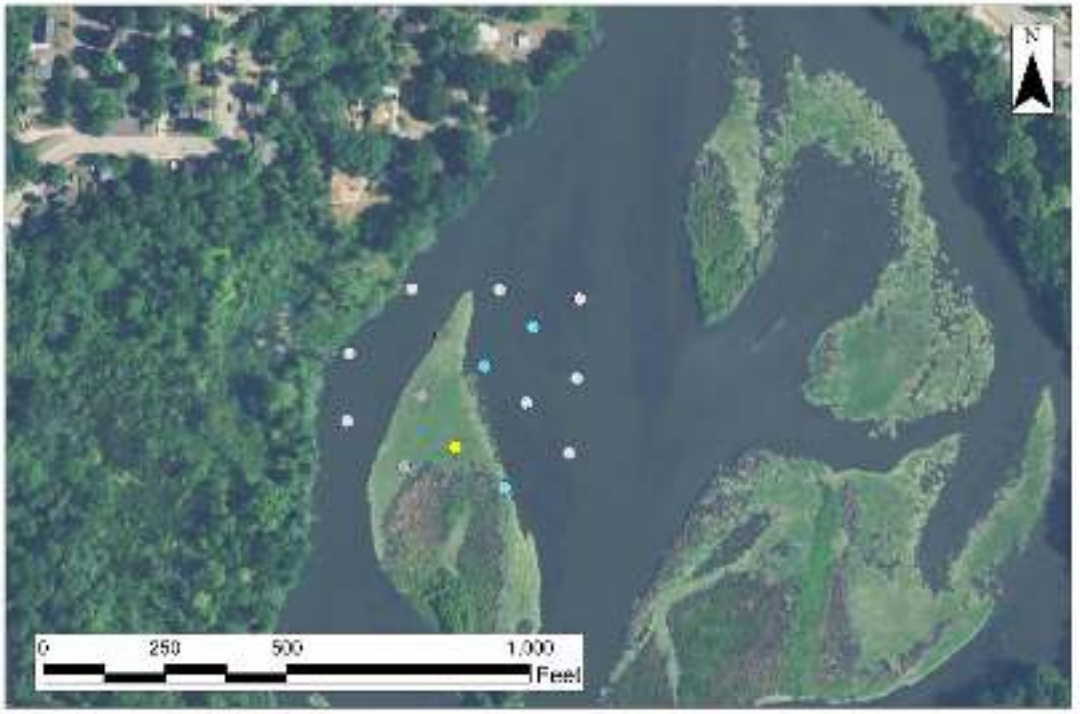
Julien, P. Y. (2010). *Erosion and Sedimentation.* Cambridge University Press.



Spatial Correlation of PCB Concentrations

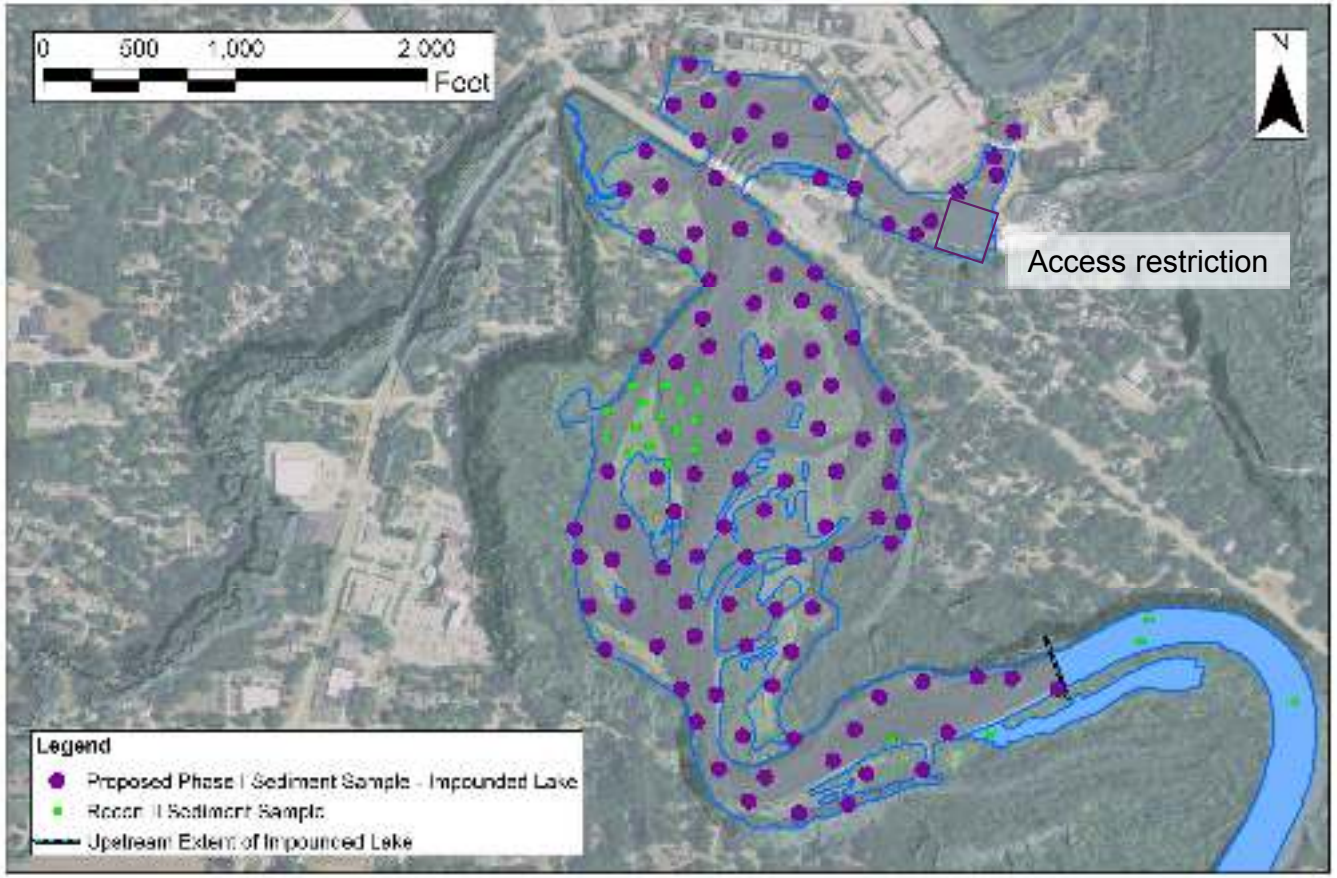
- Variograms reviewed in XY-space and using curvilinear grid (IJ-space)
- Subtle directional anisotropy
- Spatial correlation ~250 feet





Interval 4 PCB conc. shown for reference

Phase I Sampling Design for Impounded Lake



- Random origin triangular grid with randomization at each location
- 105 locations (new)
- 250 ft average spacing

Proposed Lab Analysis – Impounded Lake

All Phase I locations and intervals (105 locations):

- Total PCBs (Aroclor)

Select locations, outside Recon I & II, evenly spaced, three intervals (approximately 25 of 105 locations):

- Total Organic Carbon (TOC)
- Percent Solids
- Gradation testing (sieve/hydrometer)
- Specific gravity

Select locations, within Recon I, two subsurface intervals (approximately 10 of 105 locations)

- Total Organic Carbon (TOC)
- Percent Solids
- Gradation testing (sieve/hydrometer)
- Specific gravity

Channelized Flow Sediments

DQOs

Recon I & II Data Evaluation

Phase I SRI Sampling Design

Phase I SRI Channelized Flow Sediment

- Decision Statement (DQOs)
  - Implement an unbiased investigation strategy with a stratified, random origin that is defensible and reproducible and provides a robust dataset for statistical evaluation.
    - Bedforms are sampled at different densities with a random origin grid
  - Implement the investigation to define the vertical and horizontal extent of PCBs in bedforms. Data gaps and refinement will be performed in a Phase II SRI sample collection.
  - Estimate SWACs in sediment and perform an uncertainty analysis. (Phase I and II)

Phase I SRI Channelized Flow Sediment

- Decision Statement (DQOs)
  - Identify preliminary remedial areas at the resolution needed to support an FS (Phase I and II)
  - Collect data to support preliminary human health and ecological risk assessments. (Phase I and II)
  - Collect data to support a hydrodynamic model
  - Confirm bedform categories
  - Identify areas where additional sampling is needed to support risk assessment and FS evaluations in a Phase II event.

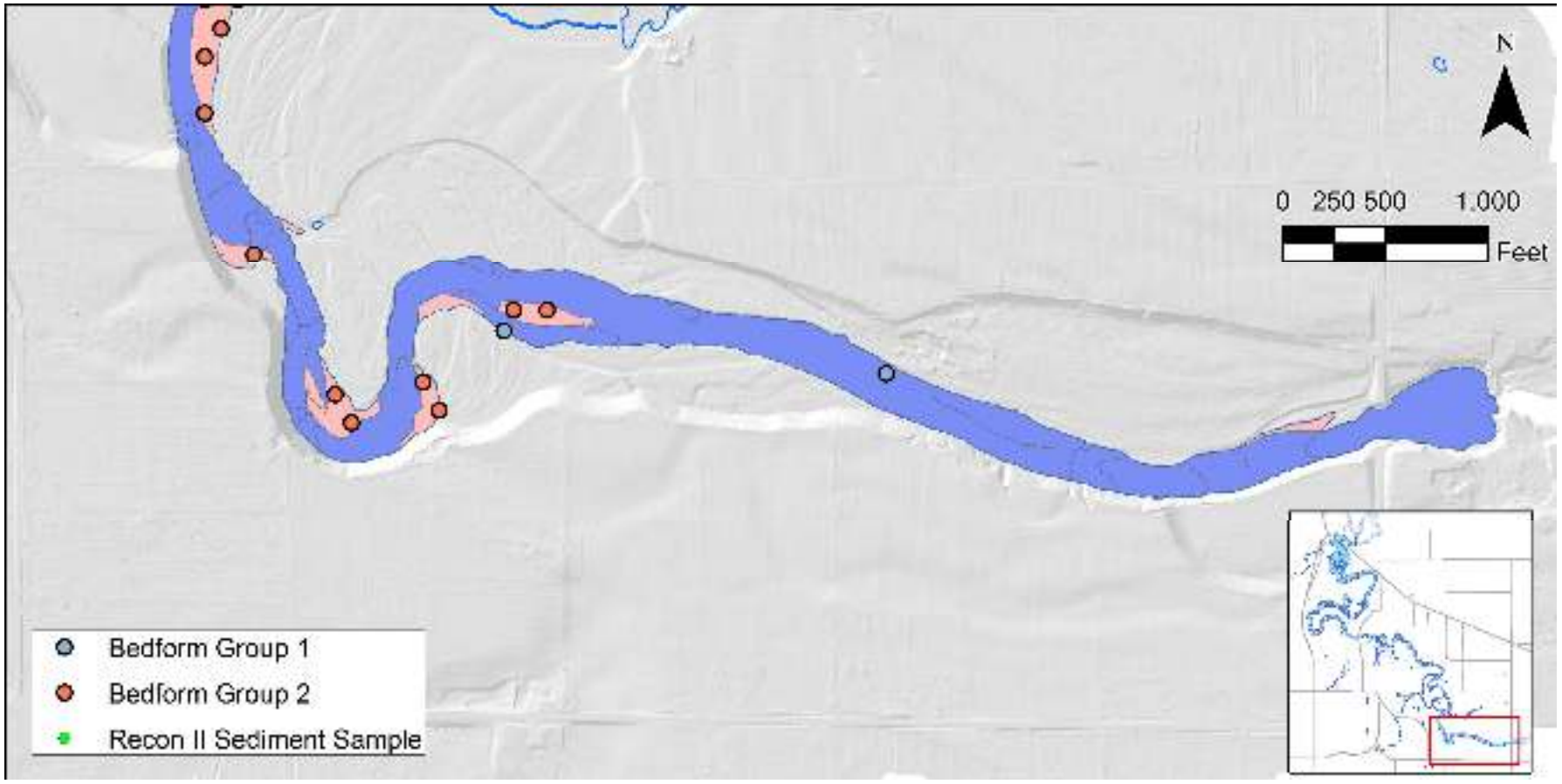
Channelized Flow Sediments

Preview of Phase I SRI Sampling Map
Recon I & II Data Evaluation
- **Pre- and Post-Recon II Bedforms**
  - **How Mapped**
  - **Sediment Thickness**
  - **Texture**
  - **PCB Data**

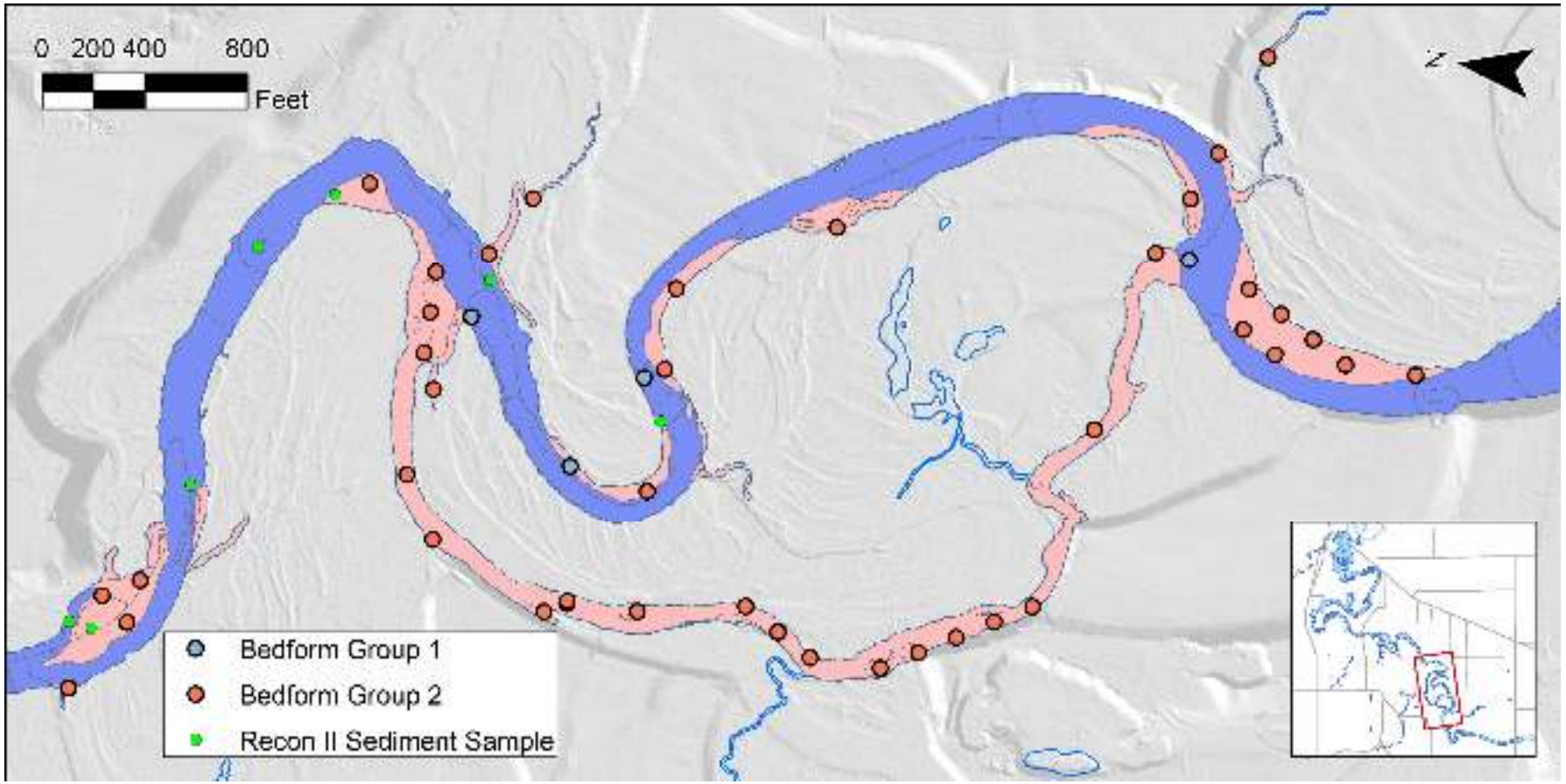
Phase I Sampling – Channelized Flow

- Stratified sampling using random origin grid
- 134 Phase I SRI sampling locations

Phase I Sampling – Channelized Flow



Phase I Sampling – Channelized Flow



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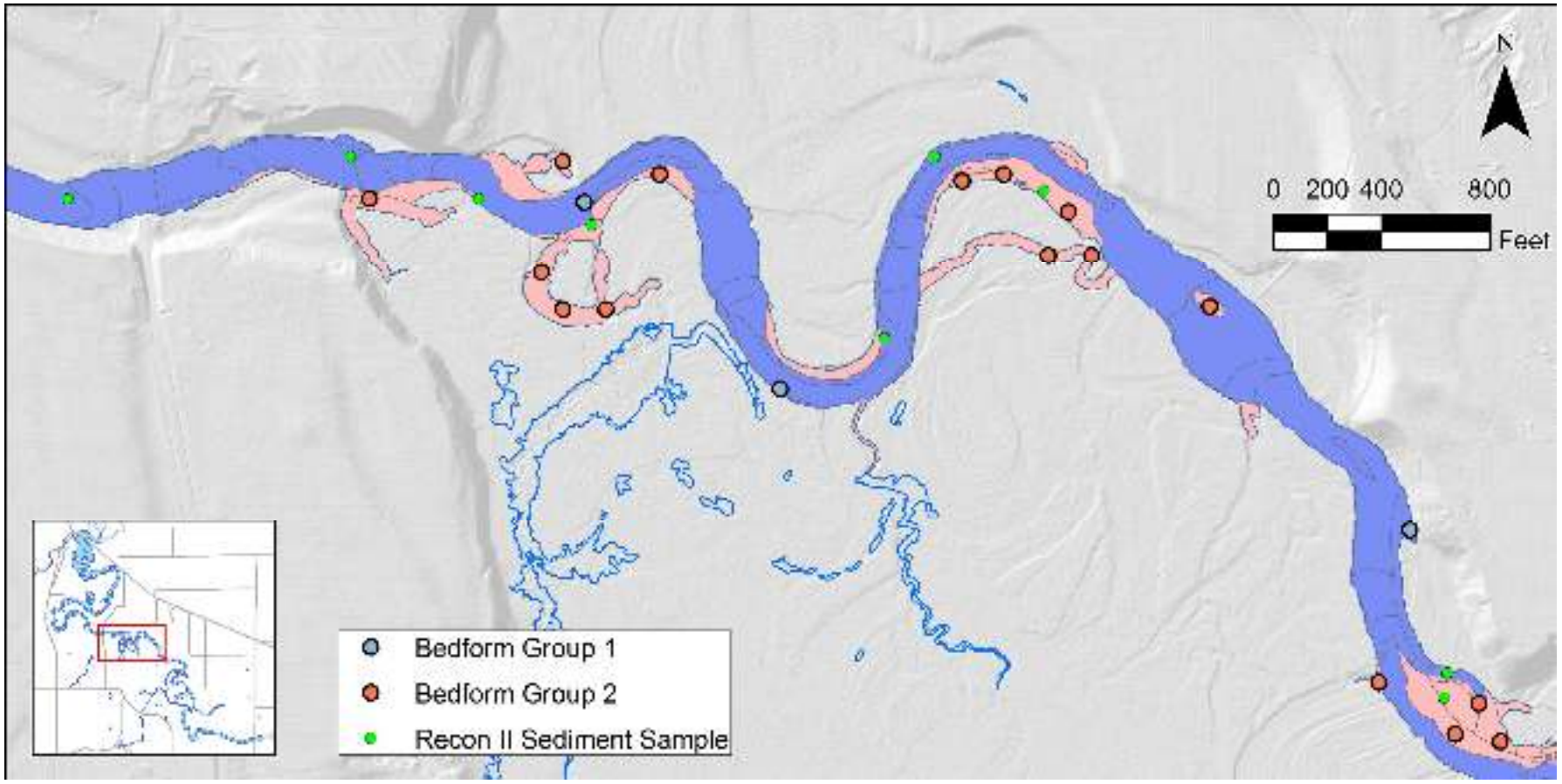
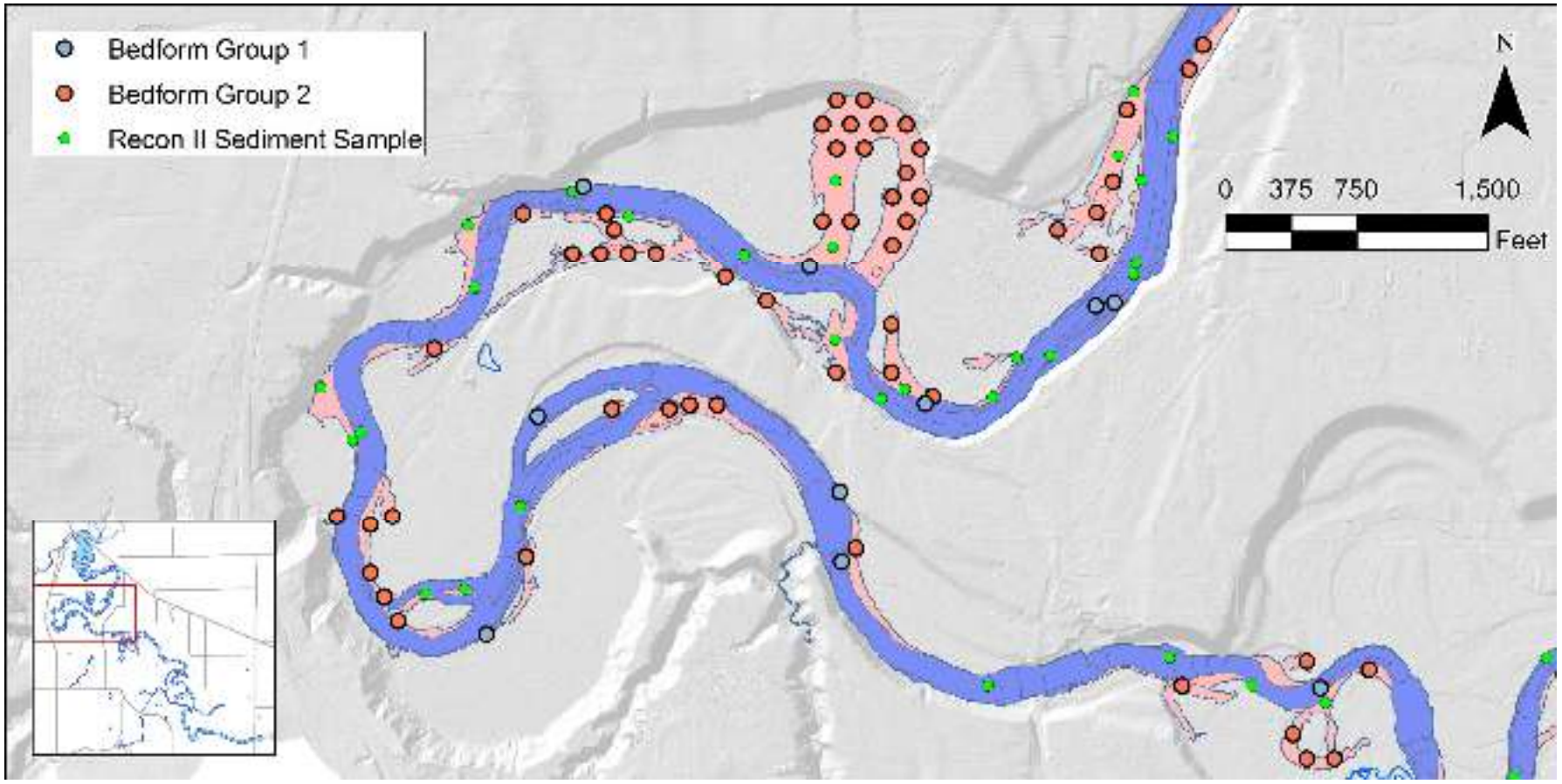
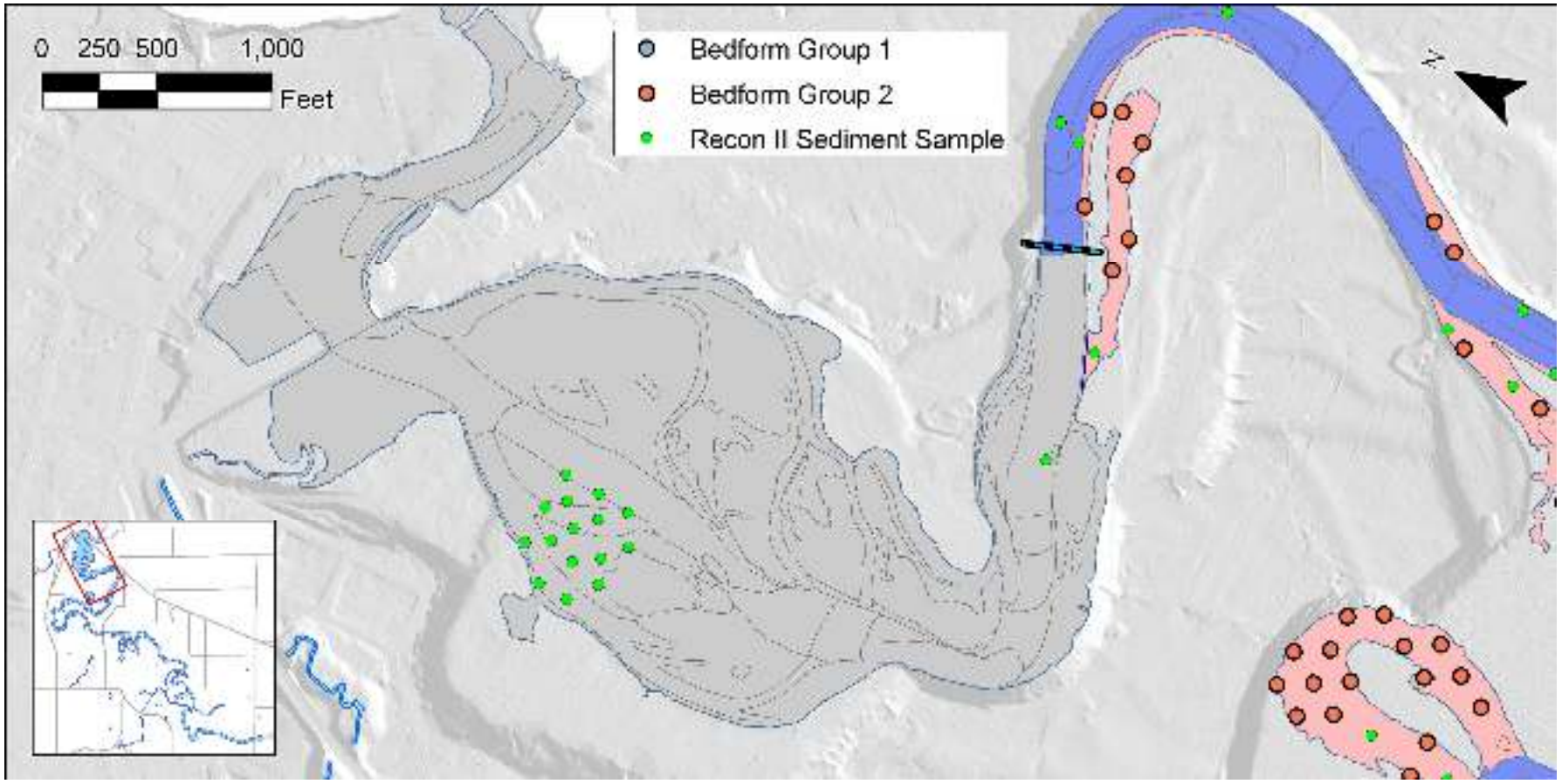


Phase I Sampling – Channelized Flow



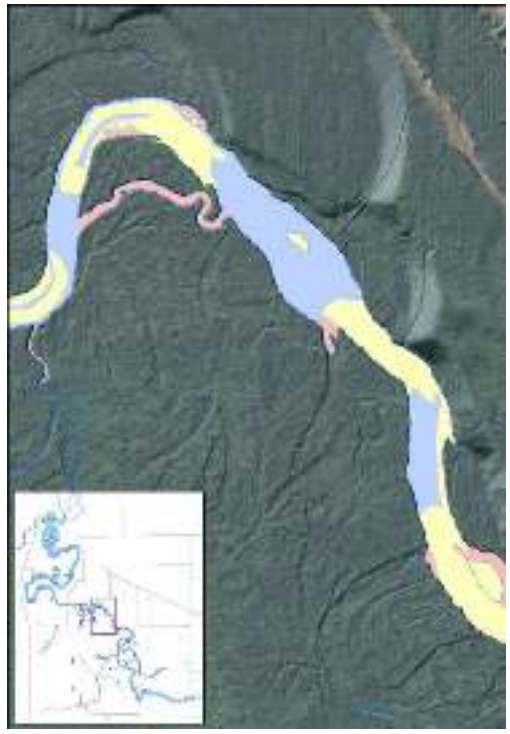
Phase I Sampling – Channelized Flow



Sediment in Channelized Flow Reach

Recon II Activities:

- 45 sediment cores – 15 in each simplified bedform group
  - Collect sufficient cores for PCB lab analysis to quantify variability
  - SedImaging to assess vertical texture consistency
  - Refine bedform stratification



Anticipated Phase I SRI Sediment Sampling Plan – Channelized Flow

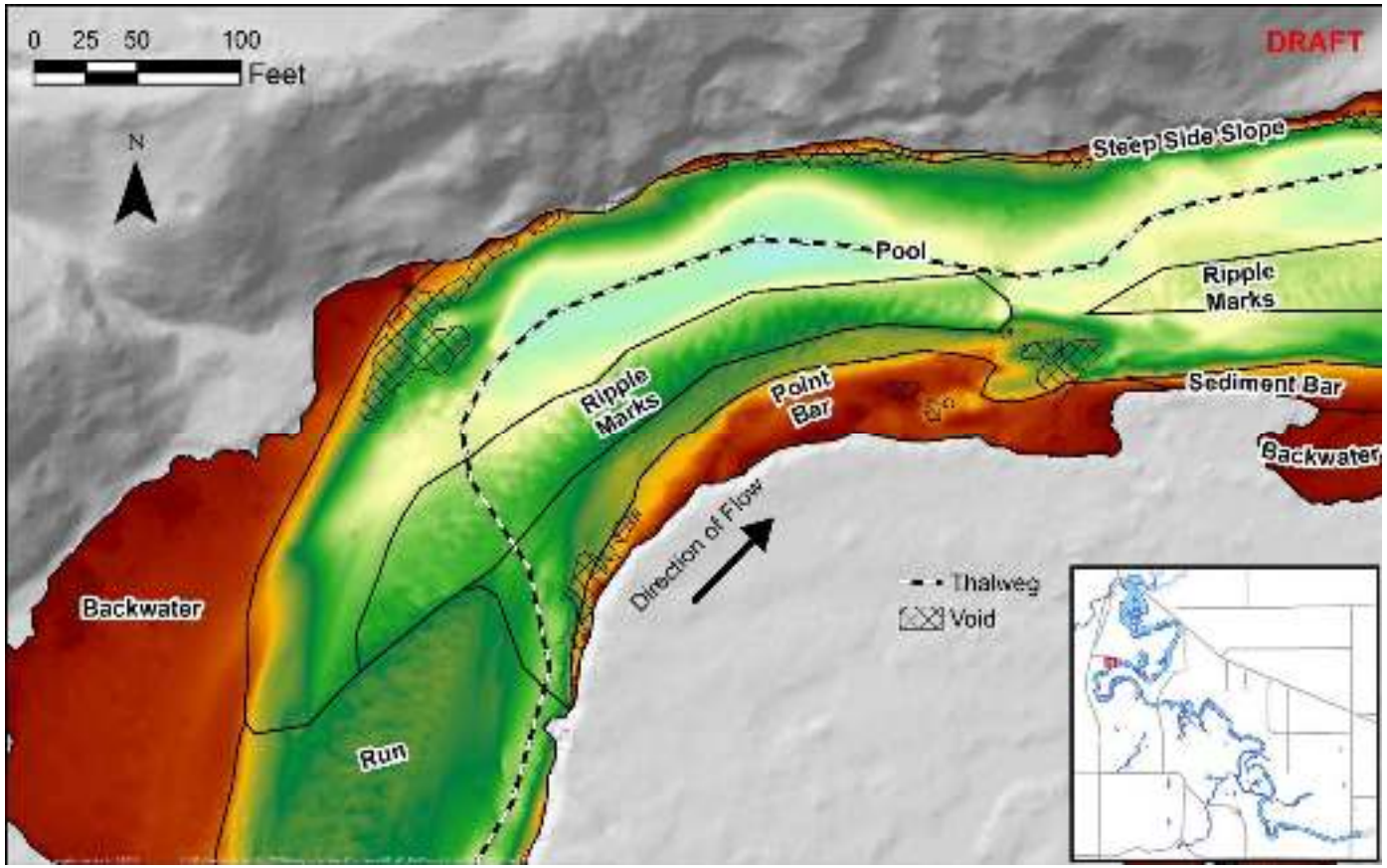
- Use stratified, random sampling to estimate SWAC
  - Use bedforms to create strata
  - Simplified bedform groups based on similar gradation
  - Sample core density based on bedform group

Results of Recon II – Channelized Flow Sediment

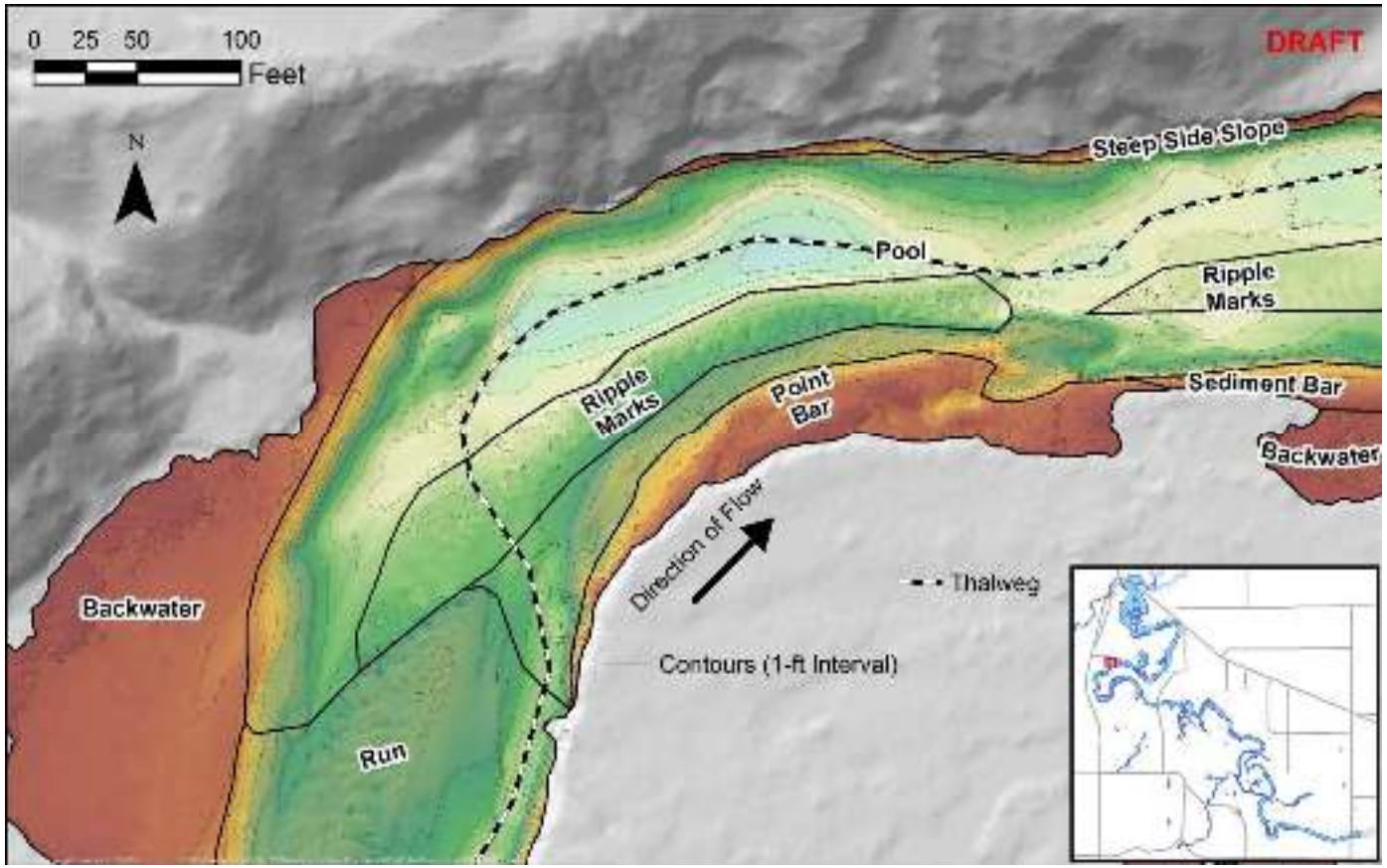
Data evaluation of Recon II data shows:

- Sediment thickness less than impounded lake
- Hydrodynamic model results generally consistent with bedforms
- Gradation data consistent with bedforms
- Gradation relatively consistent with depth
- PCB concentrations tend to be less than 0.33 mg/kg overall with exceptions (maximum 34.5 mg/kg)
- Cluster analysis shows bedforms can be simplified to two strata (groups)

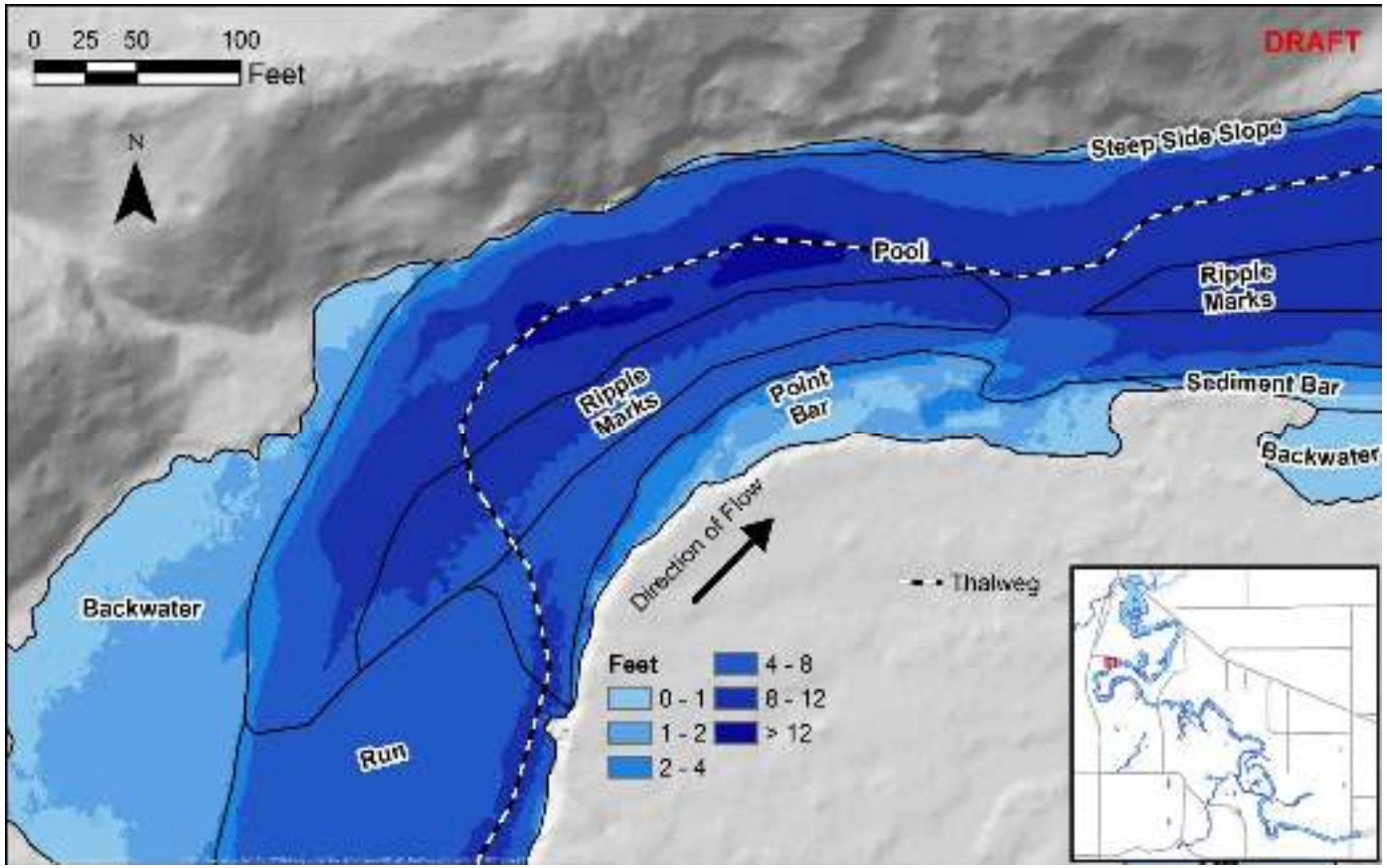
Channelized Flow – Bathymetry



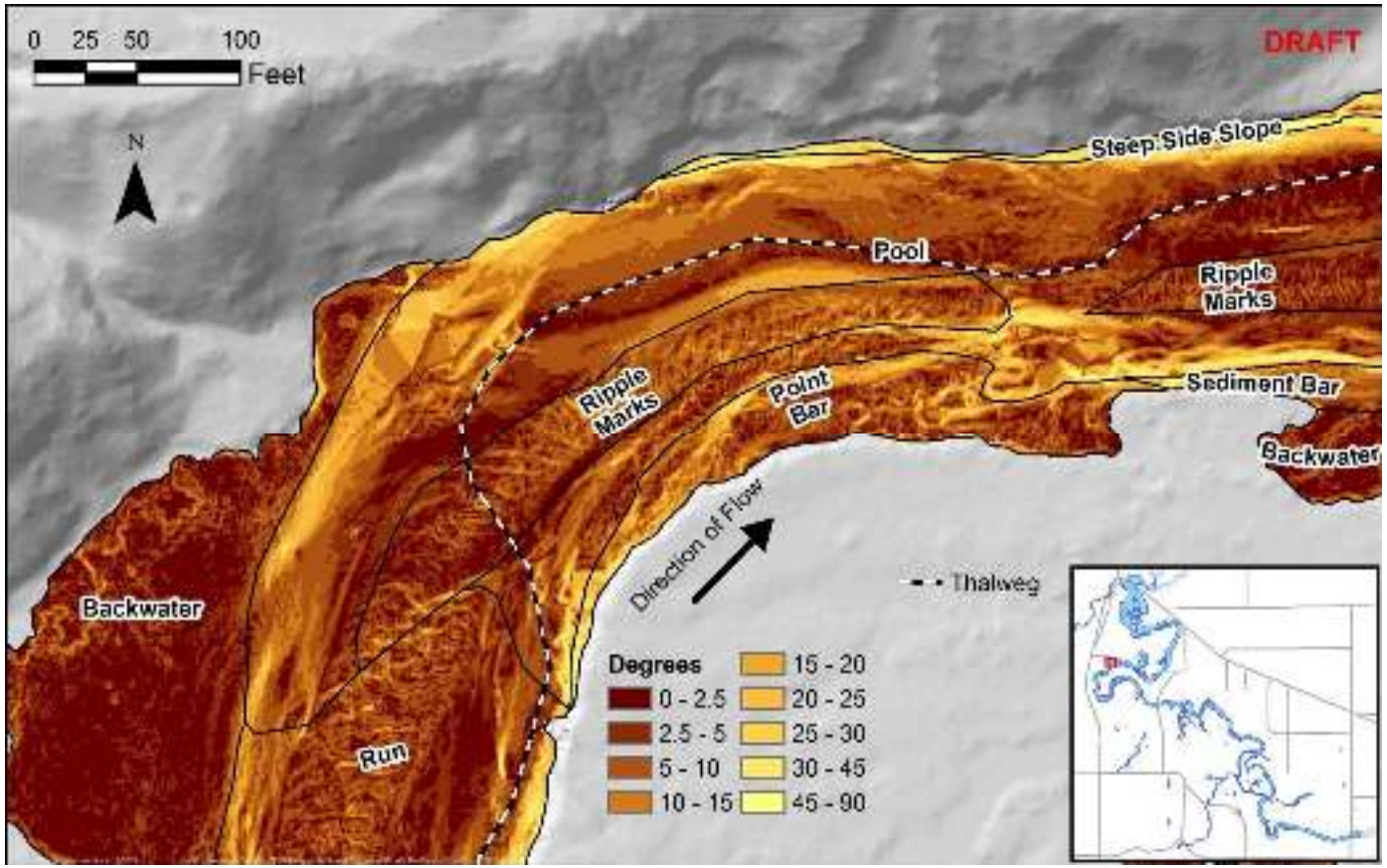
Channelized Flow– Contour over Bathymetry



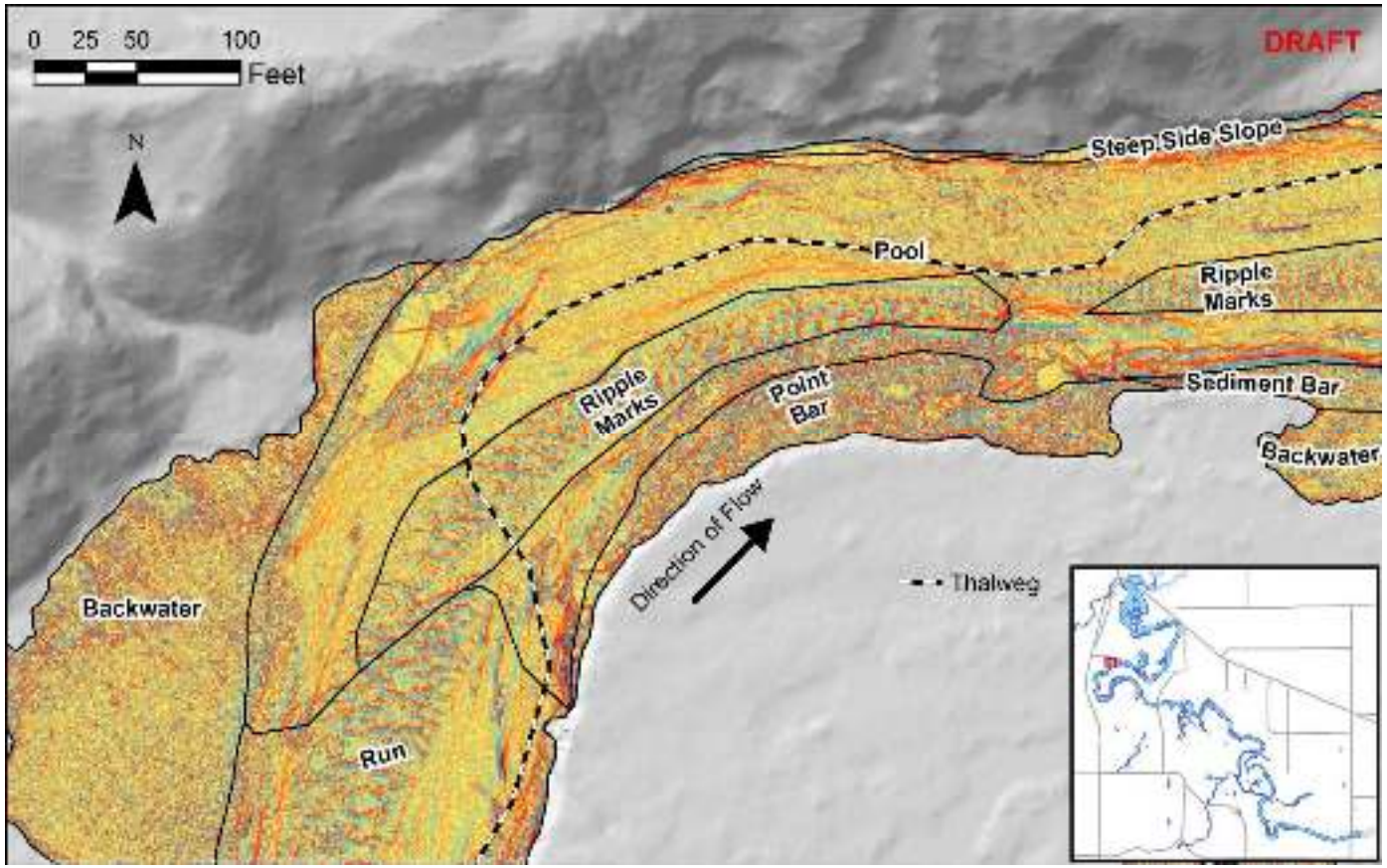
Channelized Flow– Water Depth



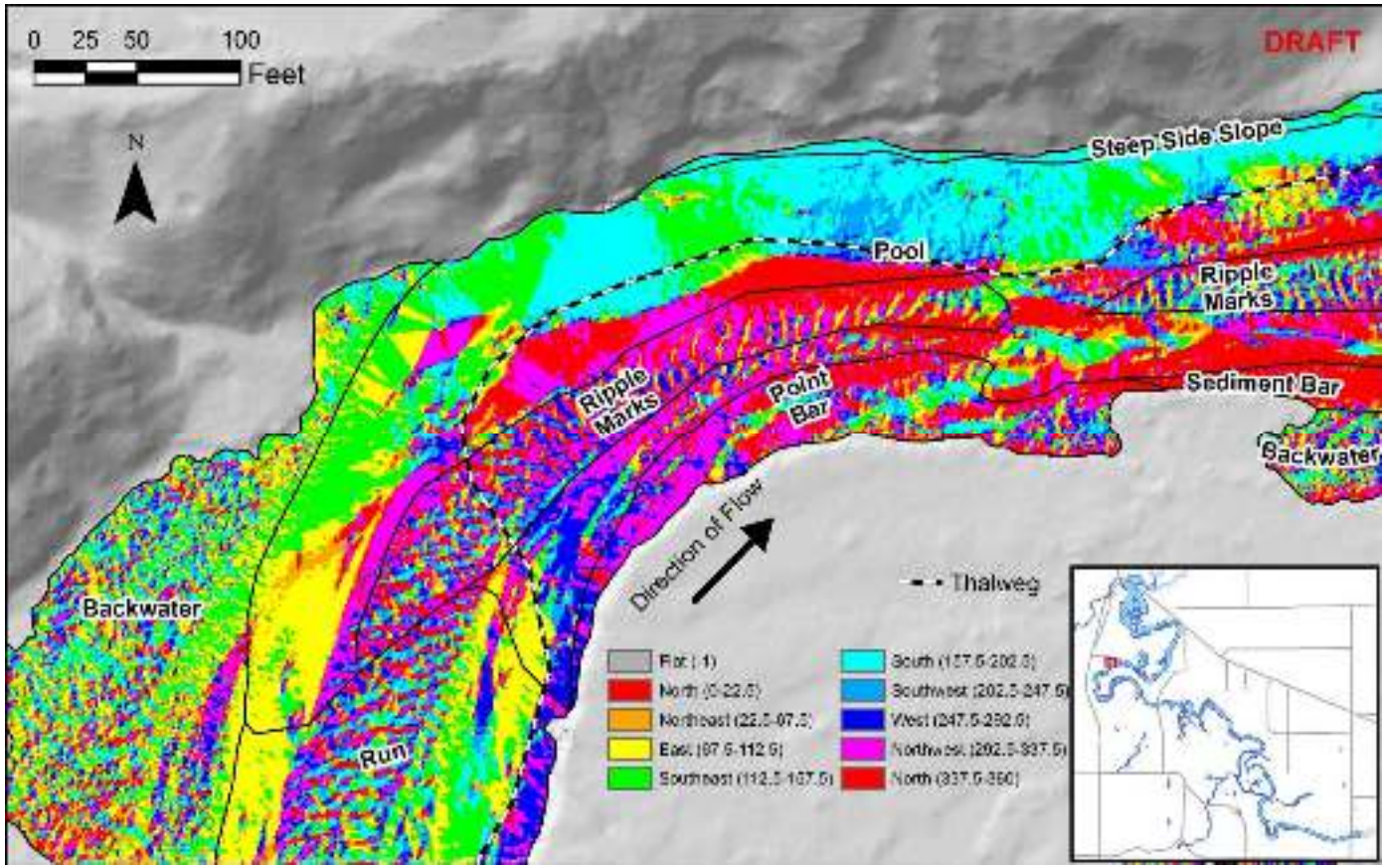
Channelized Flow– Slope



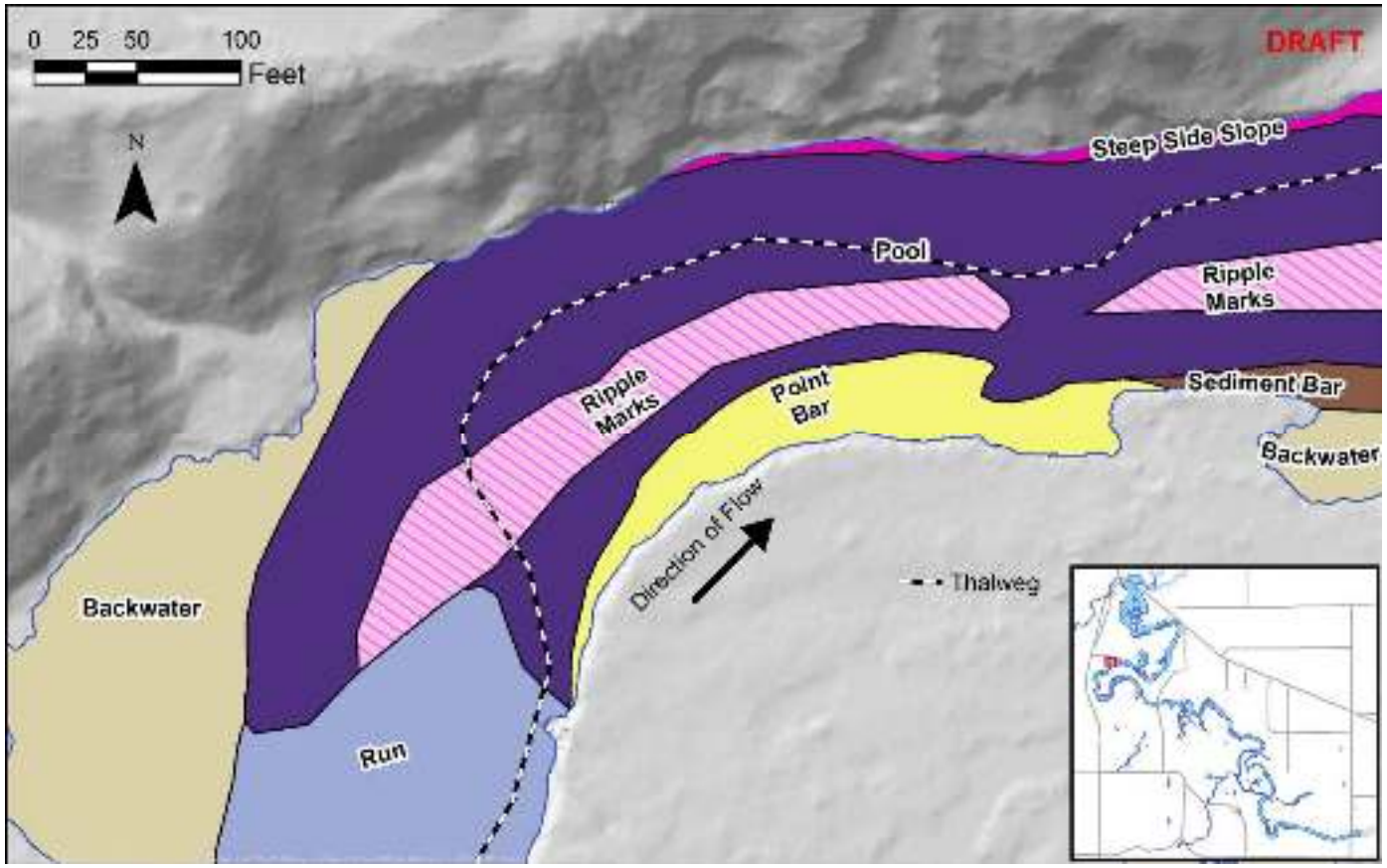
Channelized Flow– Curvature



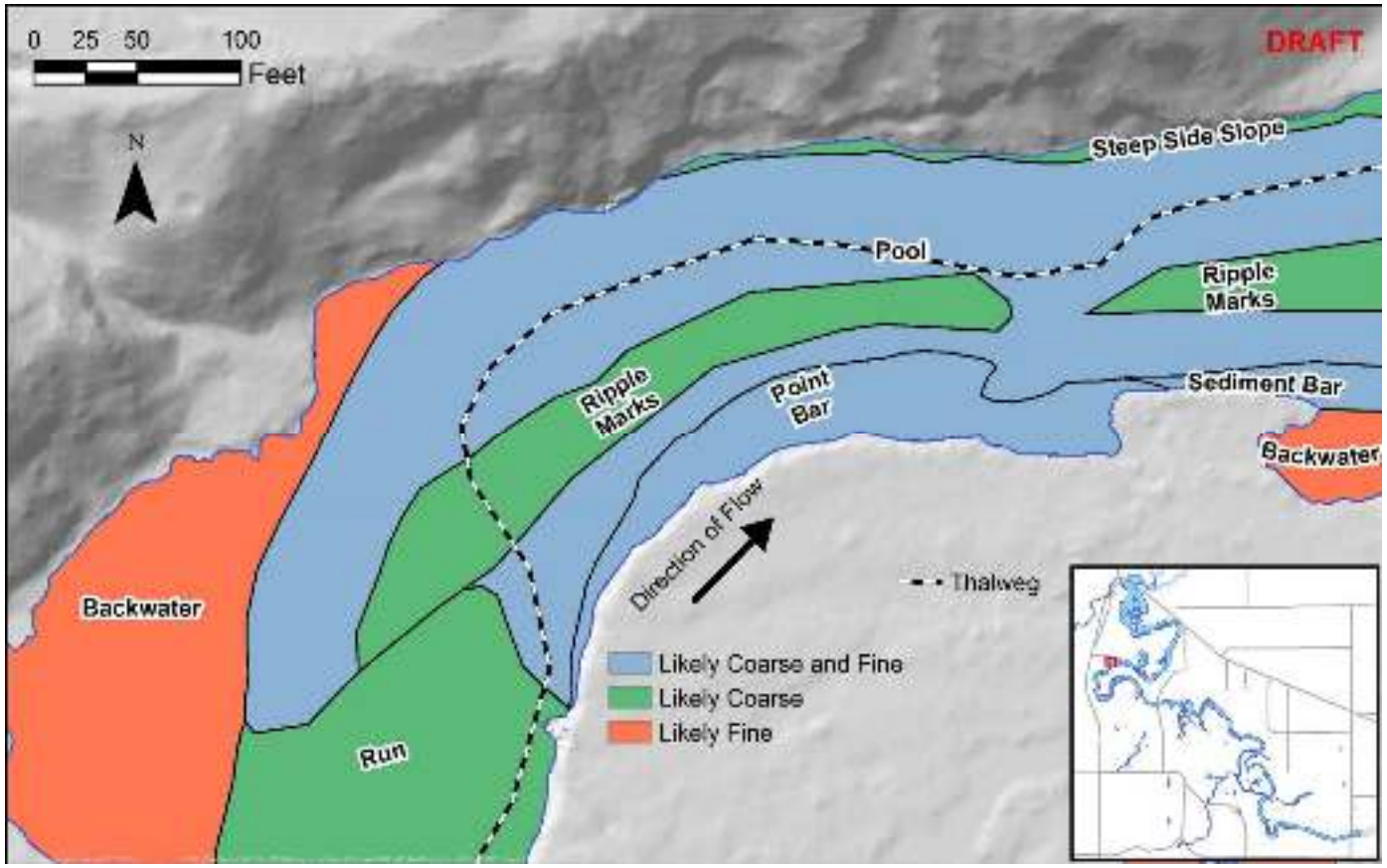
Channelized Flow– Aspect



Channelized Flow– Individual Bedform Mapping



Channelized Flow– Simplified Bedform Mapping

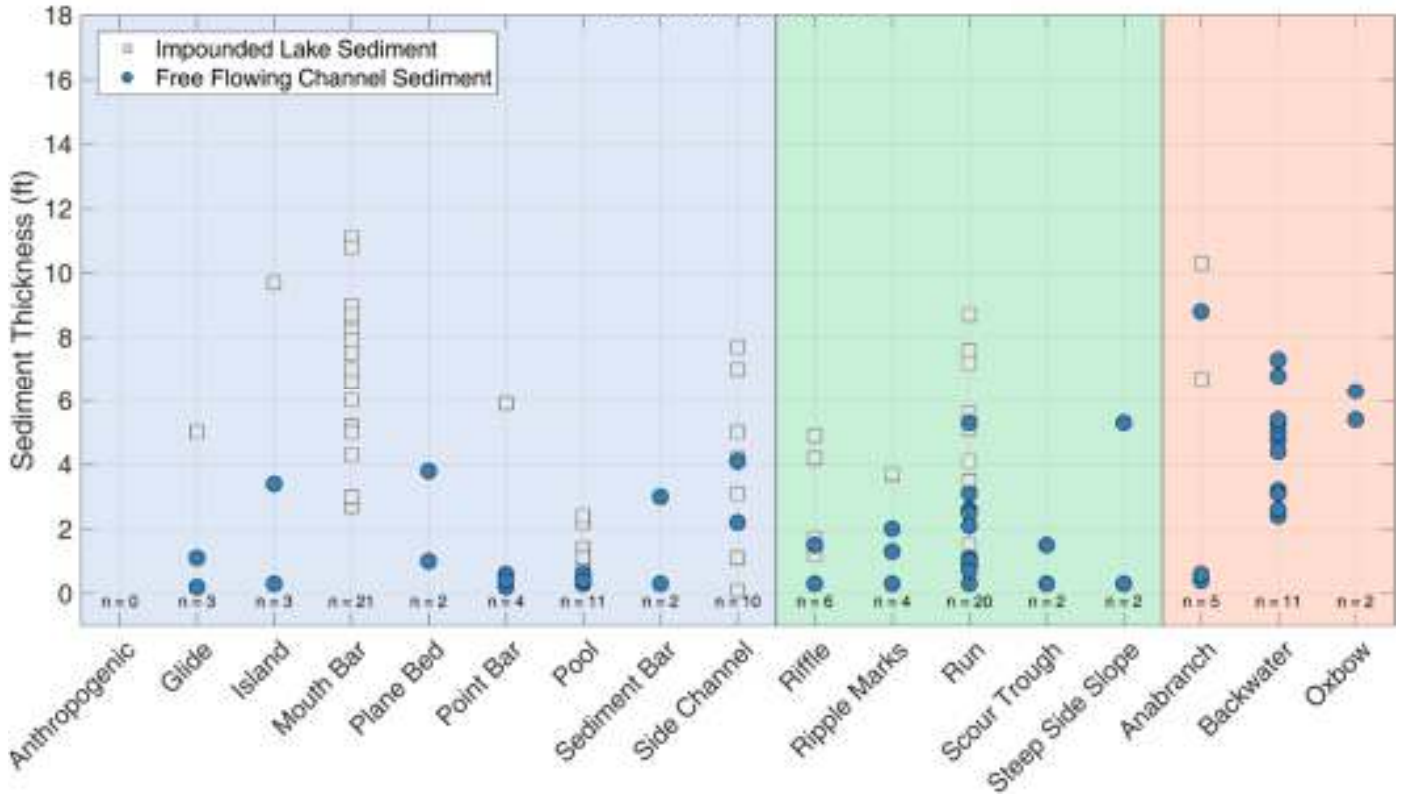


Bedform Classifications Pre-Recon II

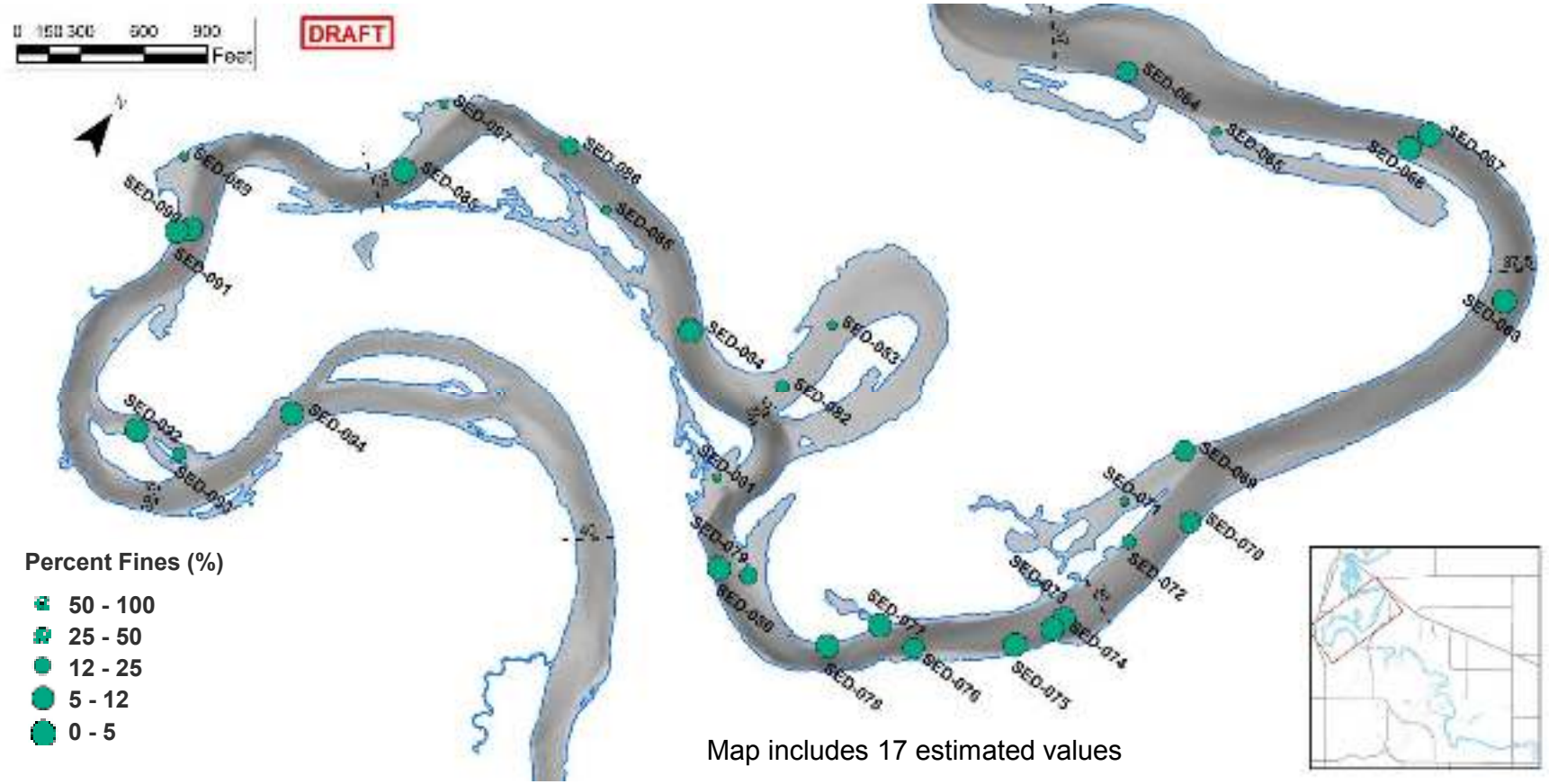
Bedform	Acreage	Simplified Category	Simplified Category Acreage
Riffle	27.8	Likely Coarse	105.9
Ripple Marks	7.7		
Run	53.6		
Scour Trough	5.0		
Steep Side Slope	11.9		
Anabranch	20.5	Likely Fine	60.2
Backwater	29.3		
Oxbow	10.4		
Anthropogenic	11.1	Likely Coarse and Fine	168.4
Glide	8.4		
Island	18.8		
Mouth Bar	34.6		
Plane Bed	5.0		
Point Bar	18.7		
Pool	46.1		
Sediment Bar	13.6		
Side Channel	12.2		
Sums	334.5		334.5

Sediment Thickness

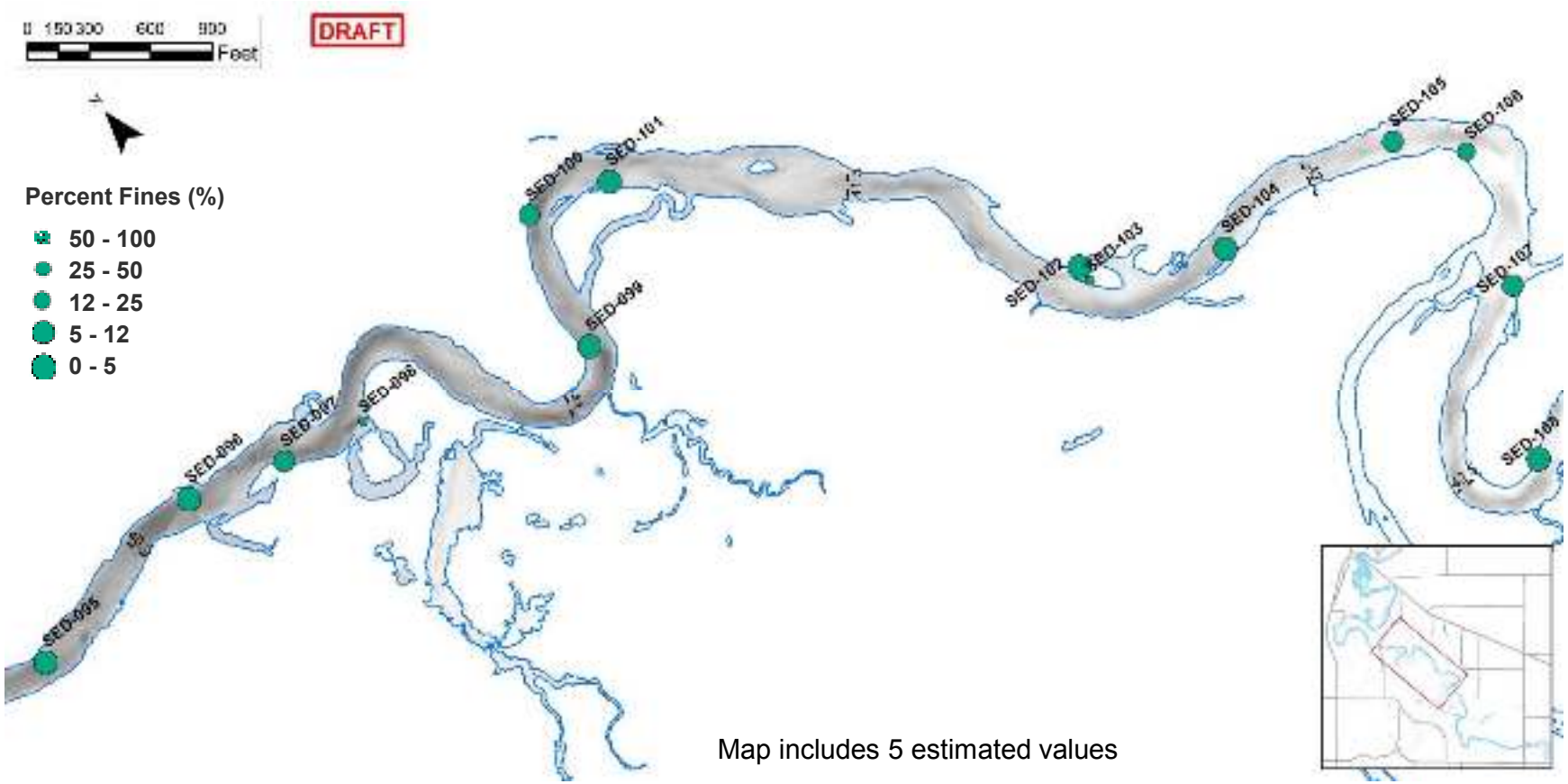
Sediment thickness variable, but generally less than impounded lake



Recon II Percent Fines – Surface

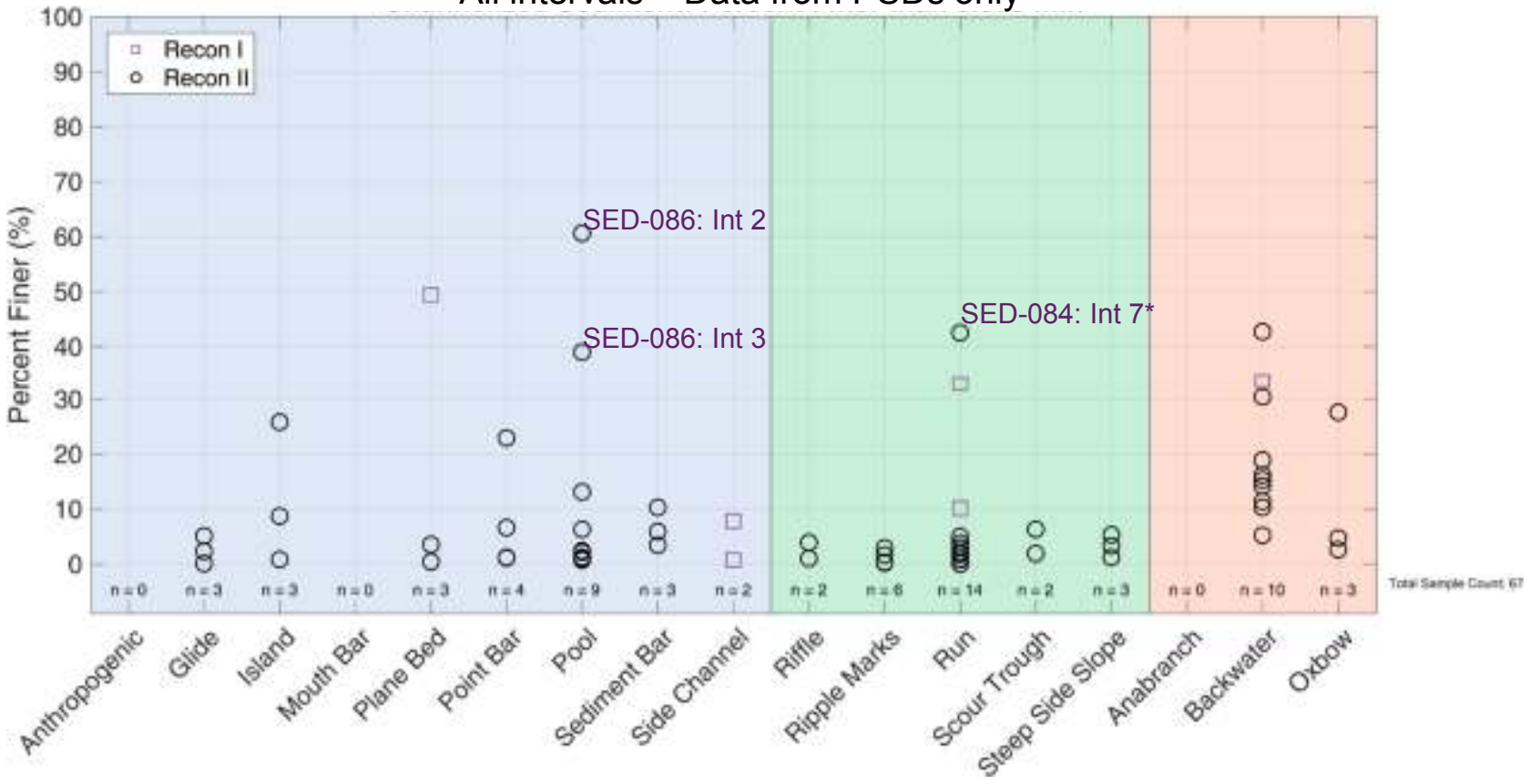


Recon II Percent Fines – Surface



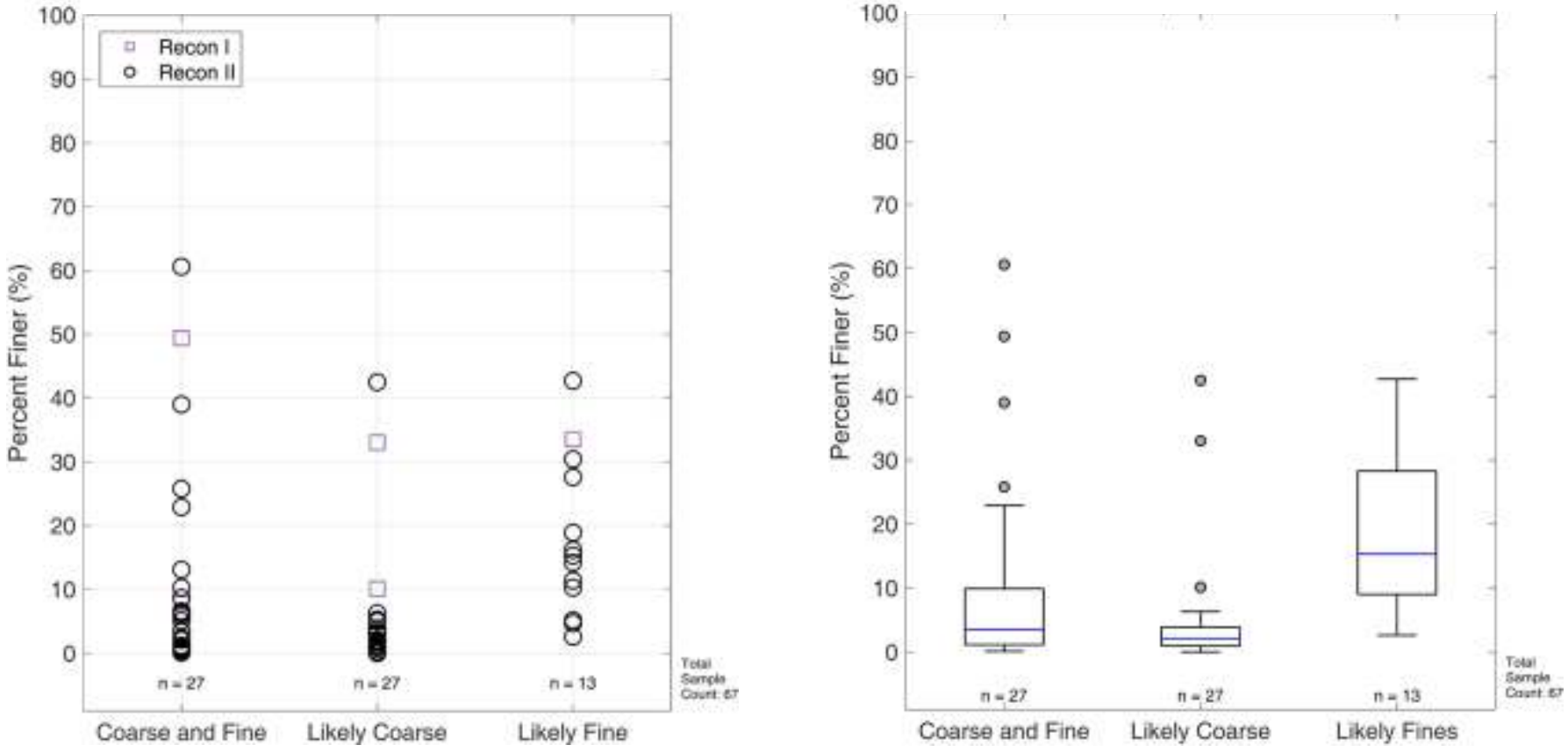
Percent Fines by Bedform

All intervals – Data from PSDs only



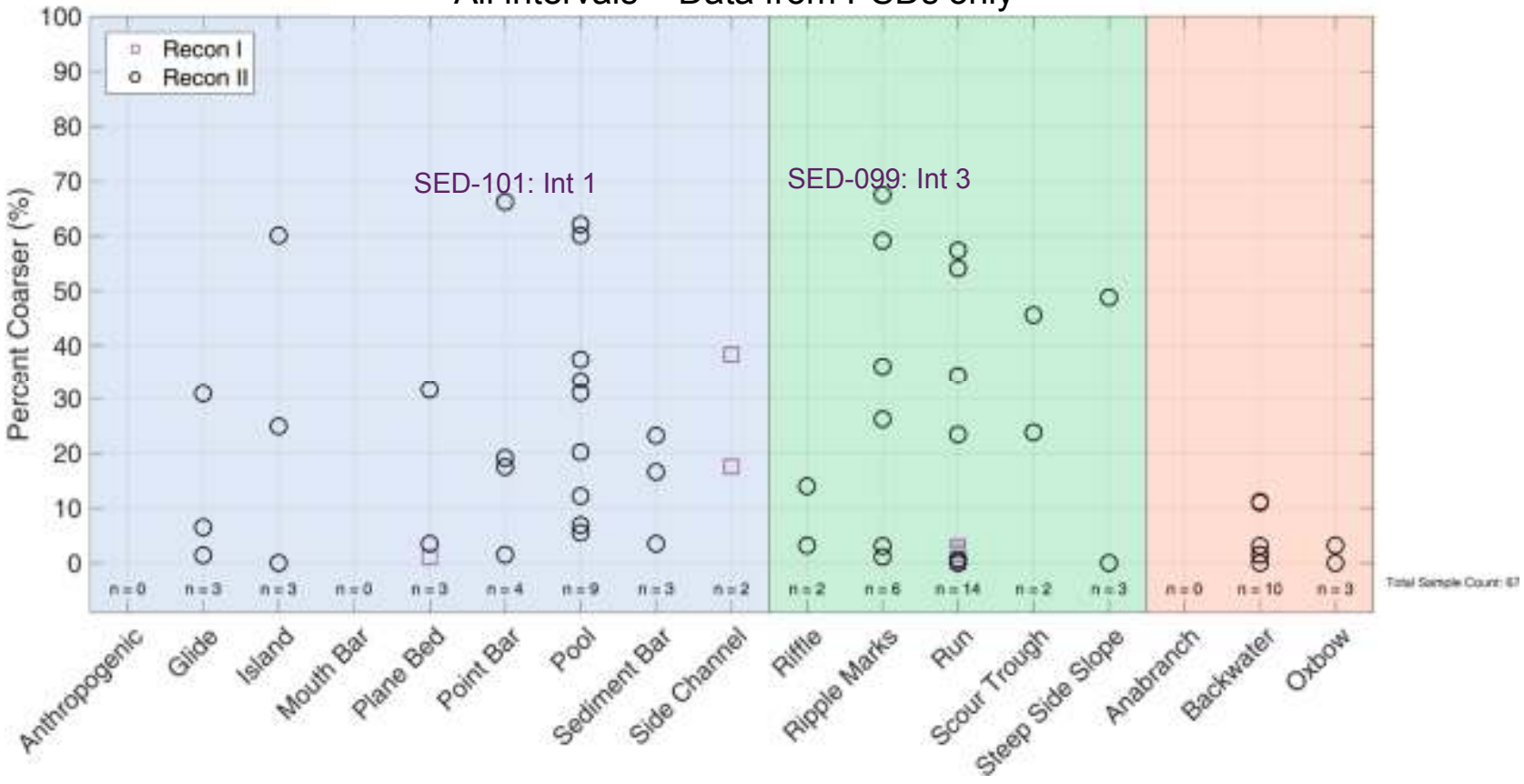
Percent Fines by Simplified Bedform

All intervals – Data from PSDs only



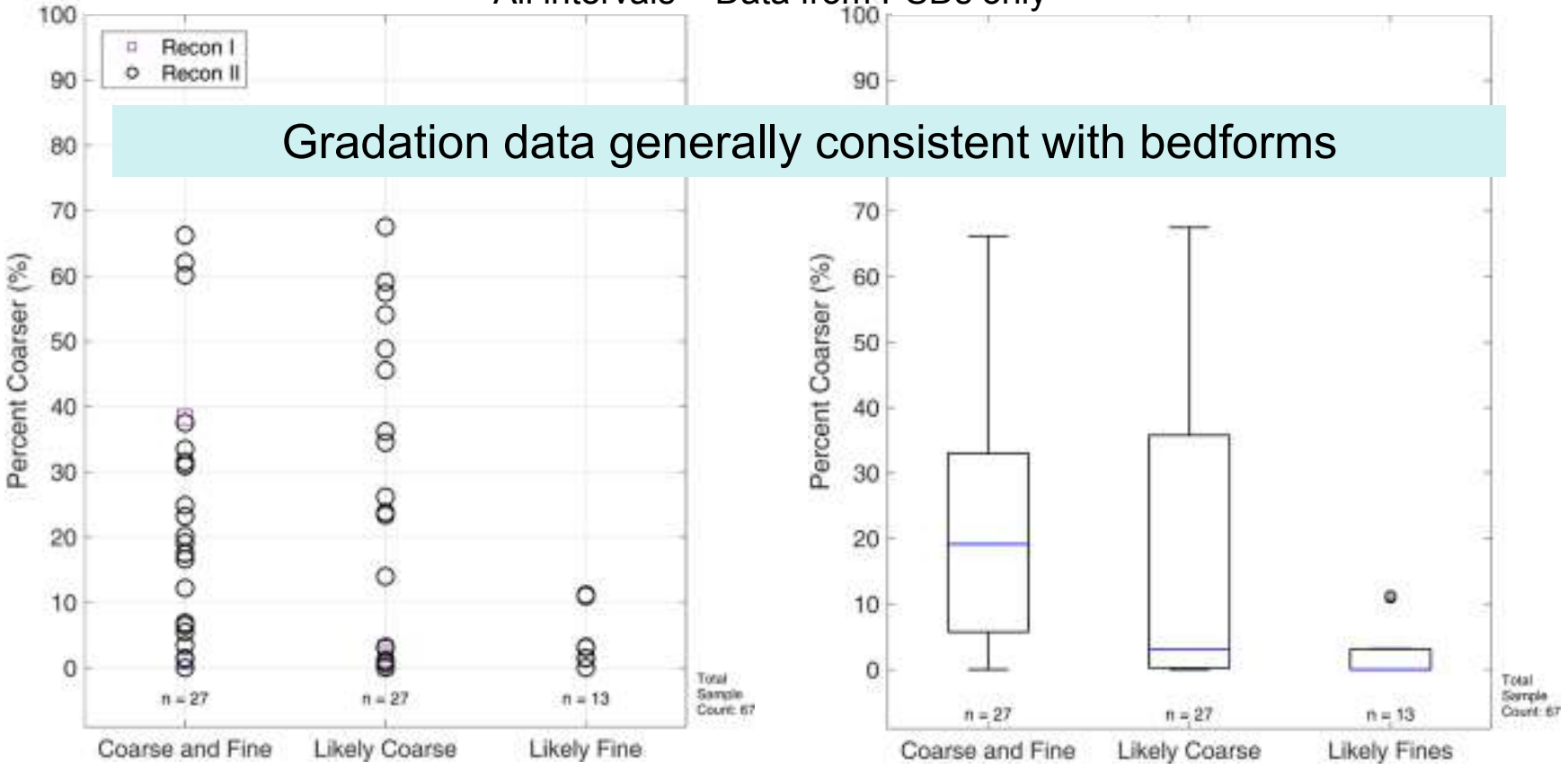
Percent Coarser than 2-mm by Bedform

All intervals – Data from PSDs only



Percent Coarser than 2-mm by Simplified Bedform

All intervals – Data from PSDs only

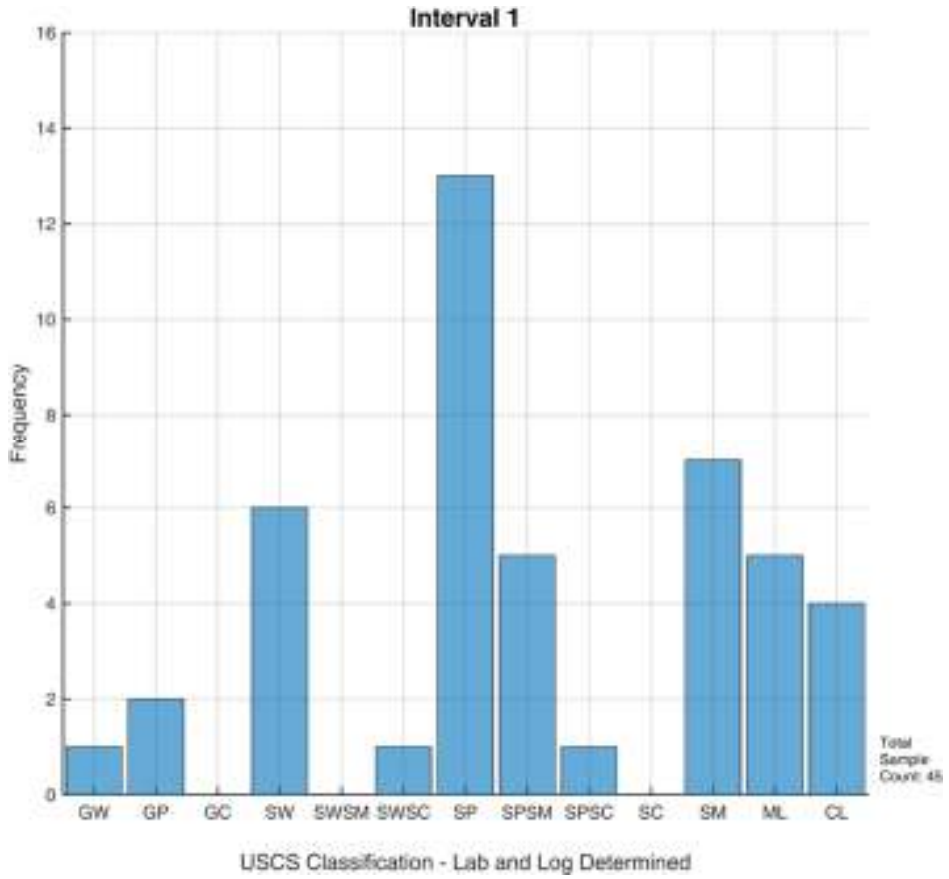


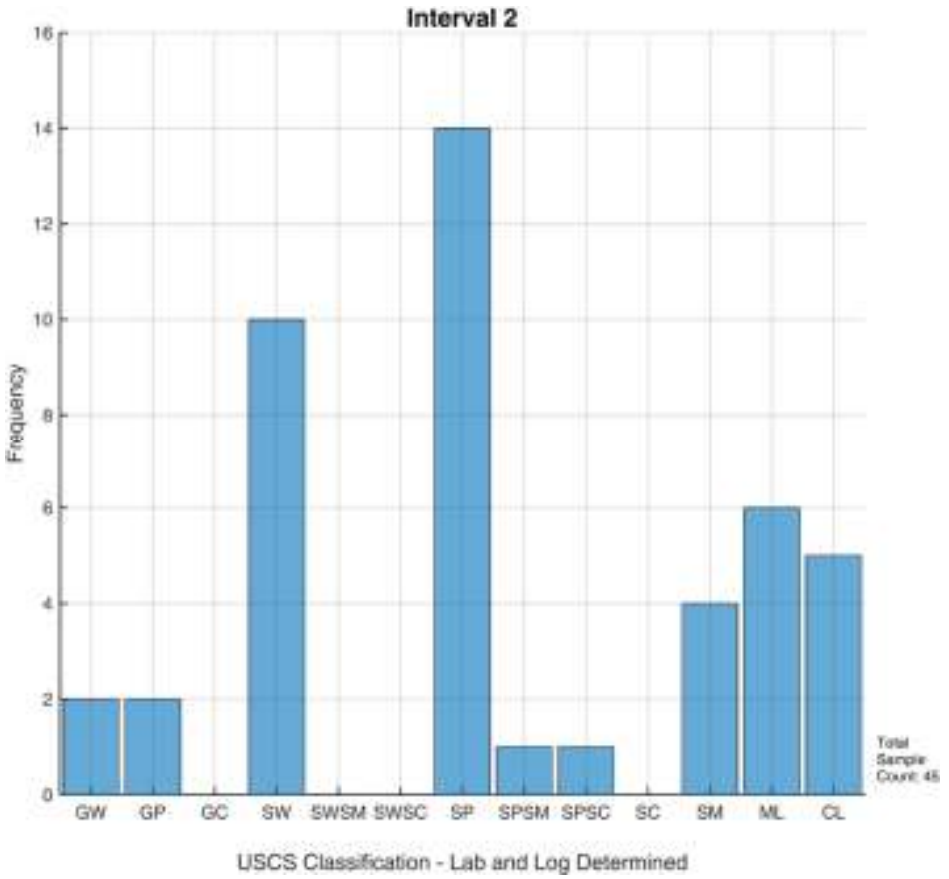
Gradation data generally consistent with bedforms

Vertical Texture Consistency

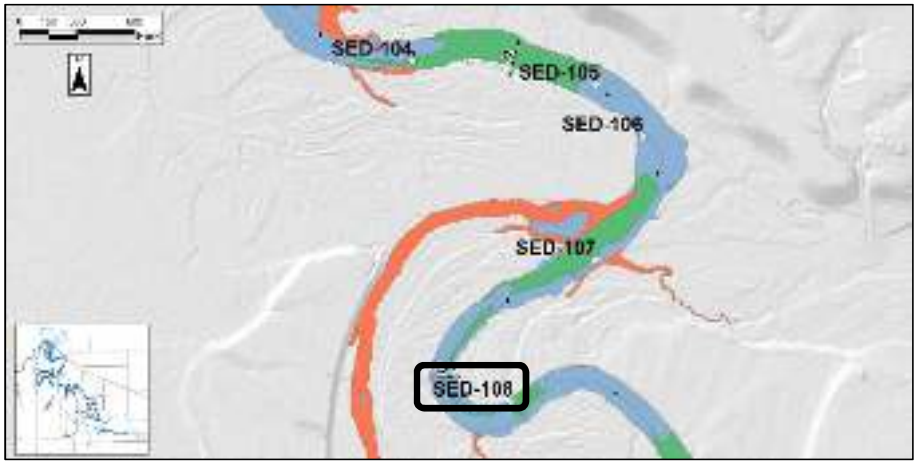
- Does the texture of sediment on the surface (Interval 1) match sediment at depth?
  - Assigned from SedImaging PSDs and USCS classifications
  - Core log photos for visual check

USCS Classification





SED-108

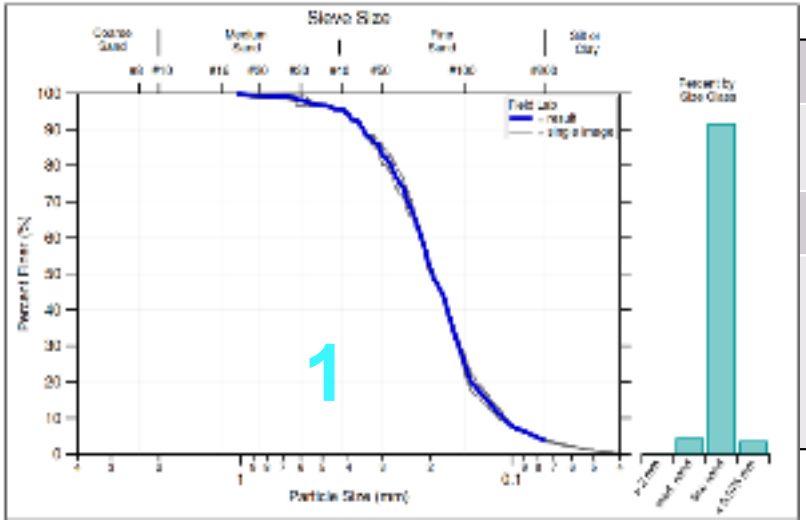


Bedforr

Soil Cla

Sedime

PCB C

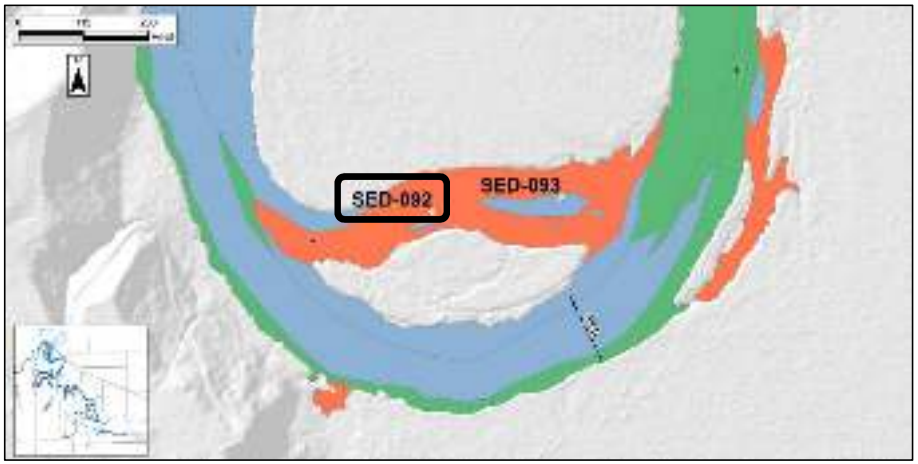


Top

Bottom

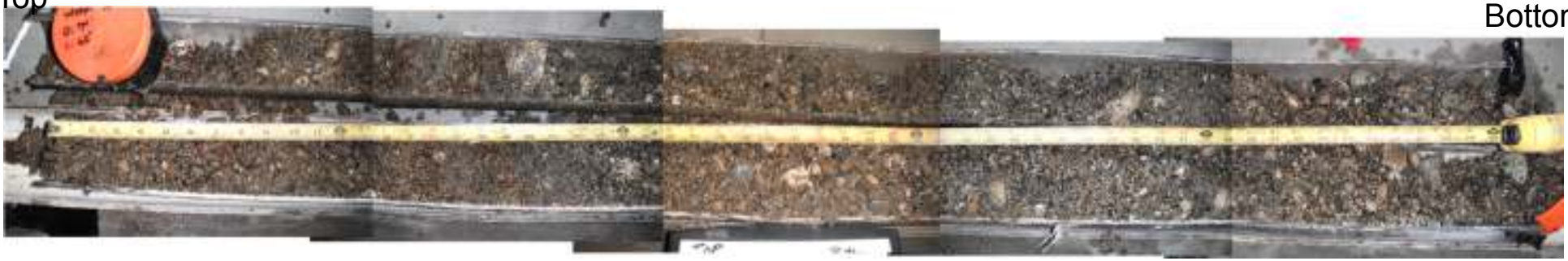
0’ 1’ 2’ 3’ 4’ 5’ 6’

SED-092



Bedform	Anabranch	
Soil Classification	Fine to coarse gravel, few cobble, some sand	
Sediment Thickness	0.4 ft	
PCB Concentration	Int 1: Int 2: Int 3: Int 4: Int 5:	0.048 JQ mg/kg 0.029 U mg/kg 0.027 U mg/kg 0.027 U mg/kg 0.027 U mg/kg

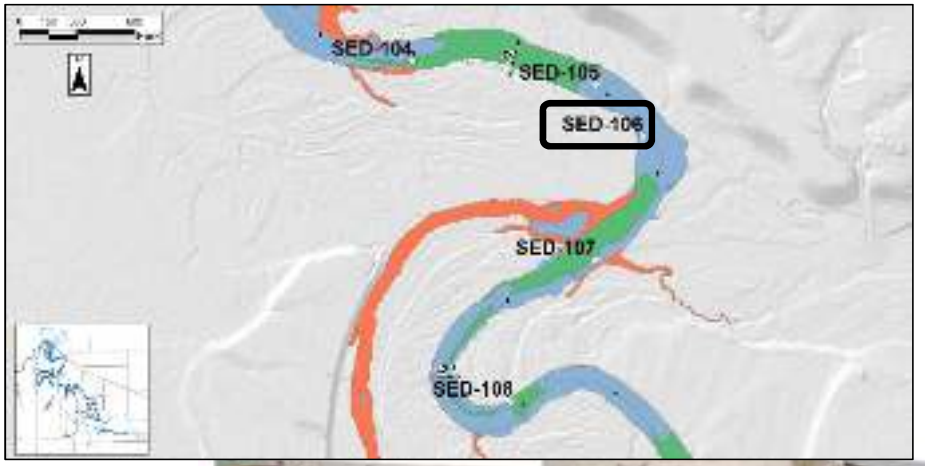
Top



Bottom

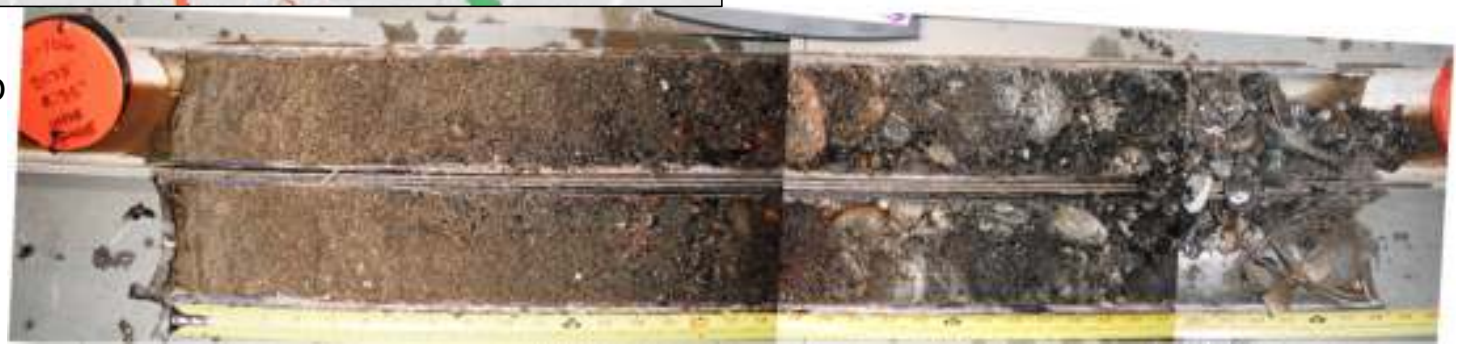
0’ 1’ 2’ 3’ 4’ 5’

SED-106



Bedform	Point Bar	
Soil Classification	Fine-medium sand, above well graded medium sand, above fine-coarse gravel	
Sediment Thickness	0.4 ft	
PCB Concentration	Int 1: Int 2: Int 3:	0.037 JQ mg/kg 0.029 JQ mg/kg 0.037 U mg/kg

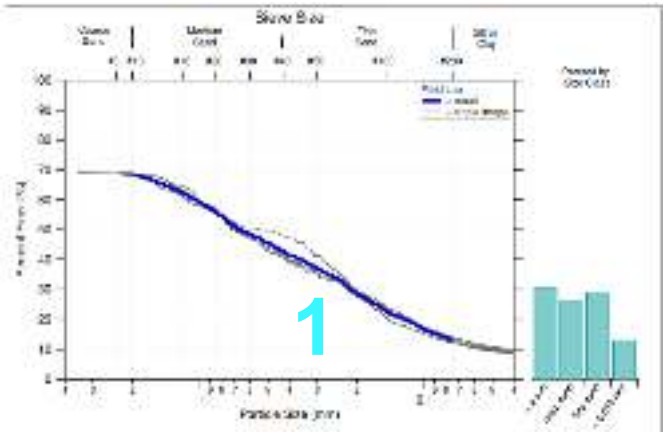
Top

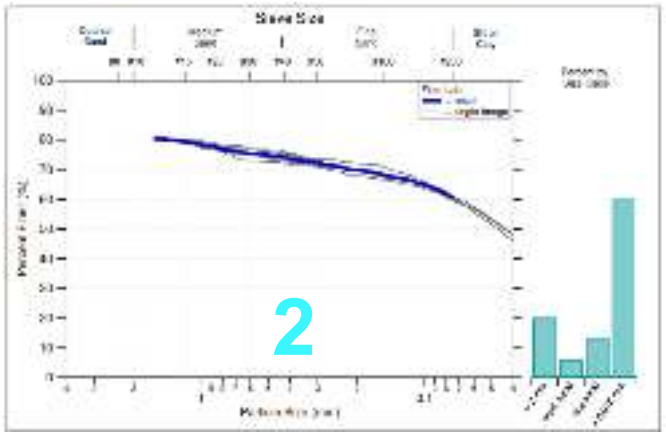


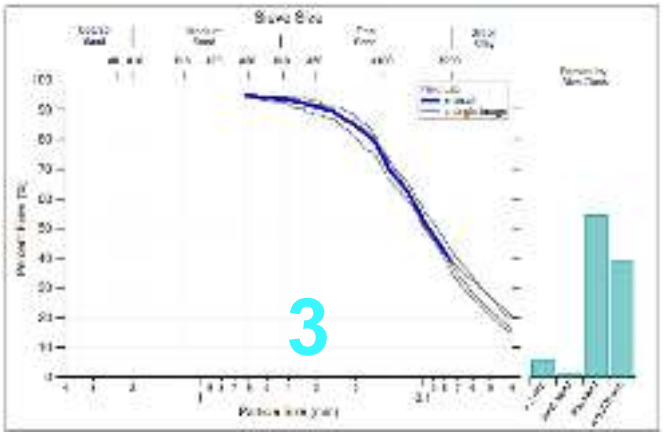
Bottom

0’ 1’ 2’ 3’

SED-086







Top

Bottom

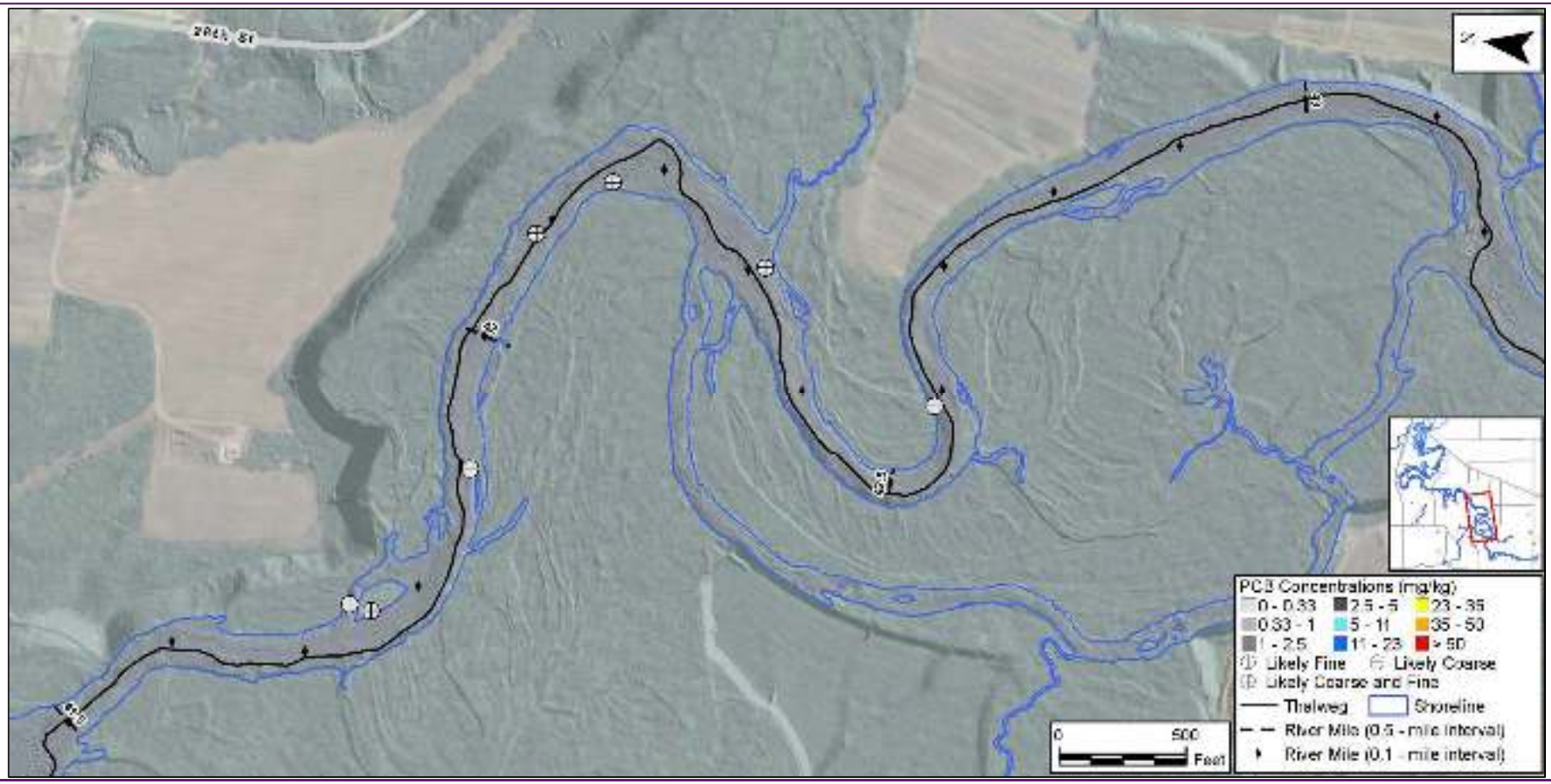
Vertical Texture Consistency Summary

- 33 of 45 cores (73%) have complete vertical consistency or fine grading to coarse
- 12 of 45 cores (27%) have coarse grading to fine:

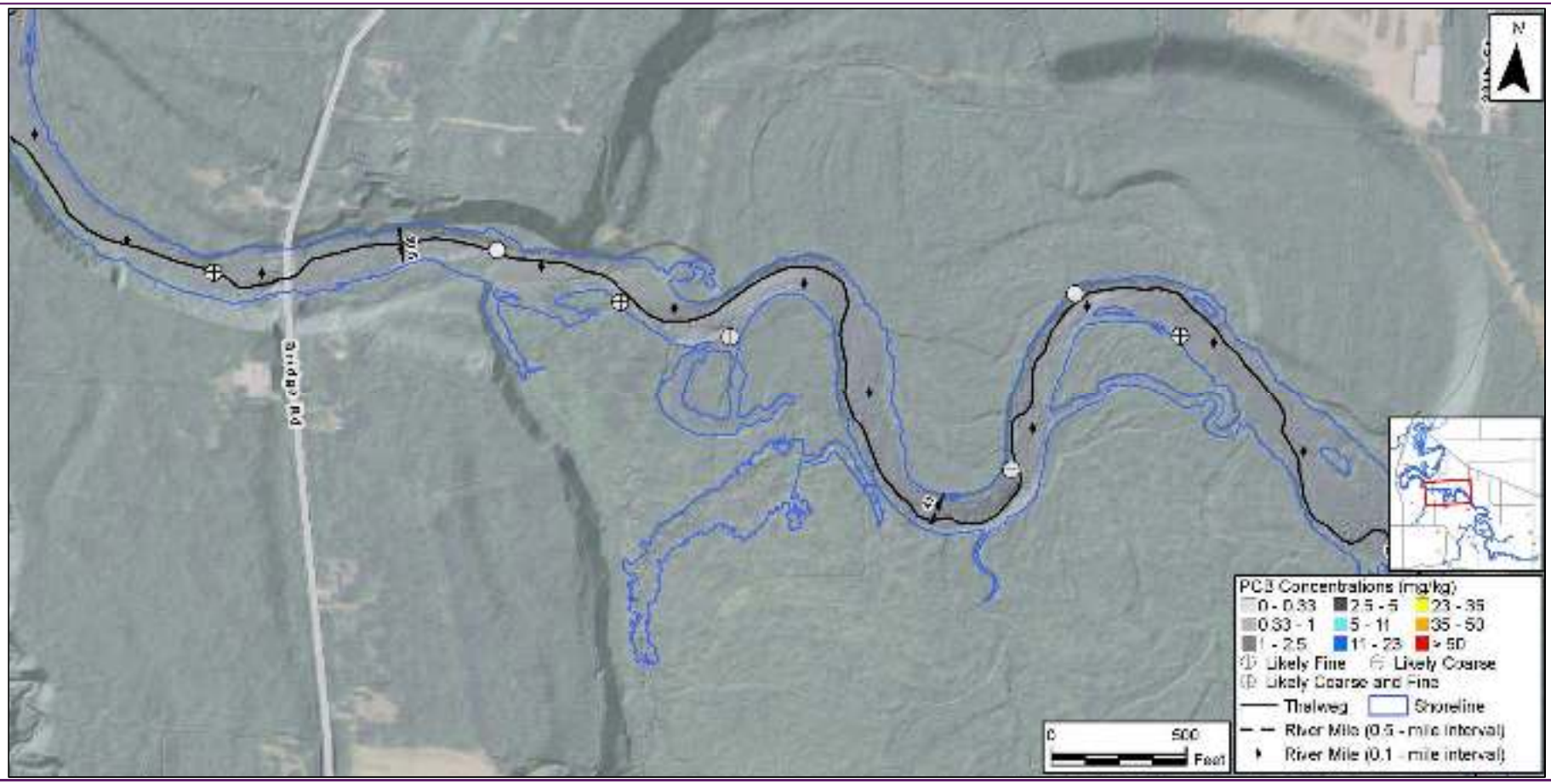
Sample	Bedform	Max PCB Conc. (mg/kg)	Simplified Category
SED-078	Steep Side Slope	0.10	Likely Coarse
SED-084	Run	0.03 U	
SED-094	Riffle	0.03 U	
SED-088	Plane Bed	0.13	Likely Coarse and Fine
SED-067	Pool	0.03 U	
SED-086	Pool	0.03 U	
SED-097	Point Bar	0.03 U	
SED-082	Oxbow	33	Likely Fine
SED-077	Backwater	6.8	
SED-091	Backwater	2.6	
SED-069	Backwater	0.26	
SED-079	Backwater	0.13	

Differences in vertical texture indicate that additional bedform samples are appropriate in Phase I in all bedforms; however, sample densities should be consistent throughout the bedform.

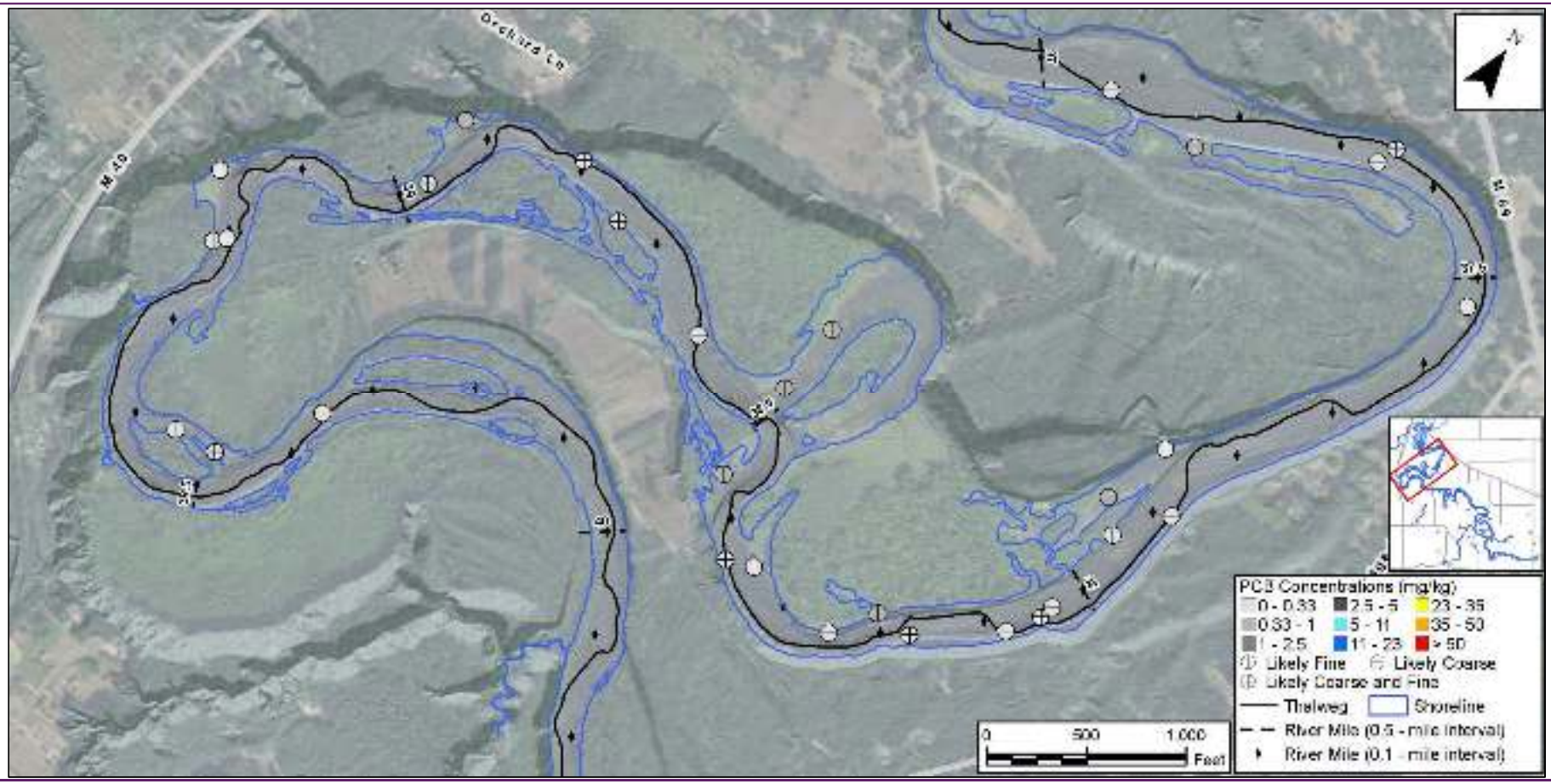
Recon II PCBs, Interval 1 – Channelized Flow



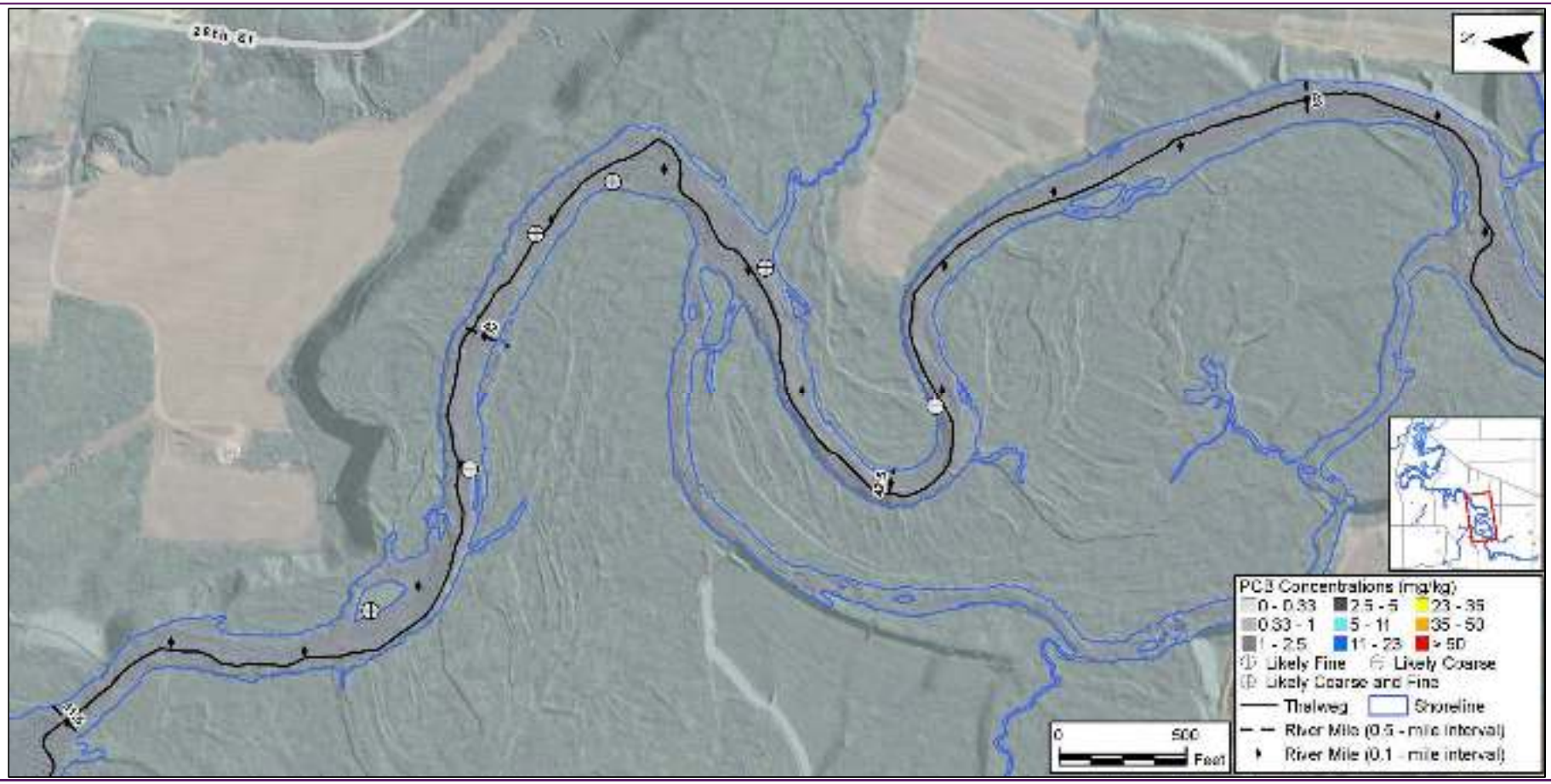
Recon II PCBs, Interval 1 – Channelized Flow



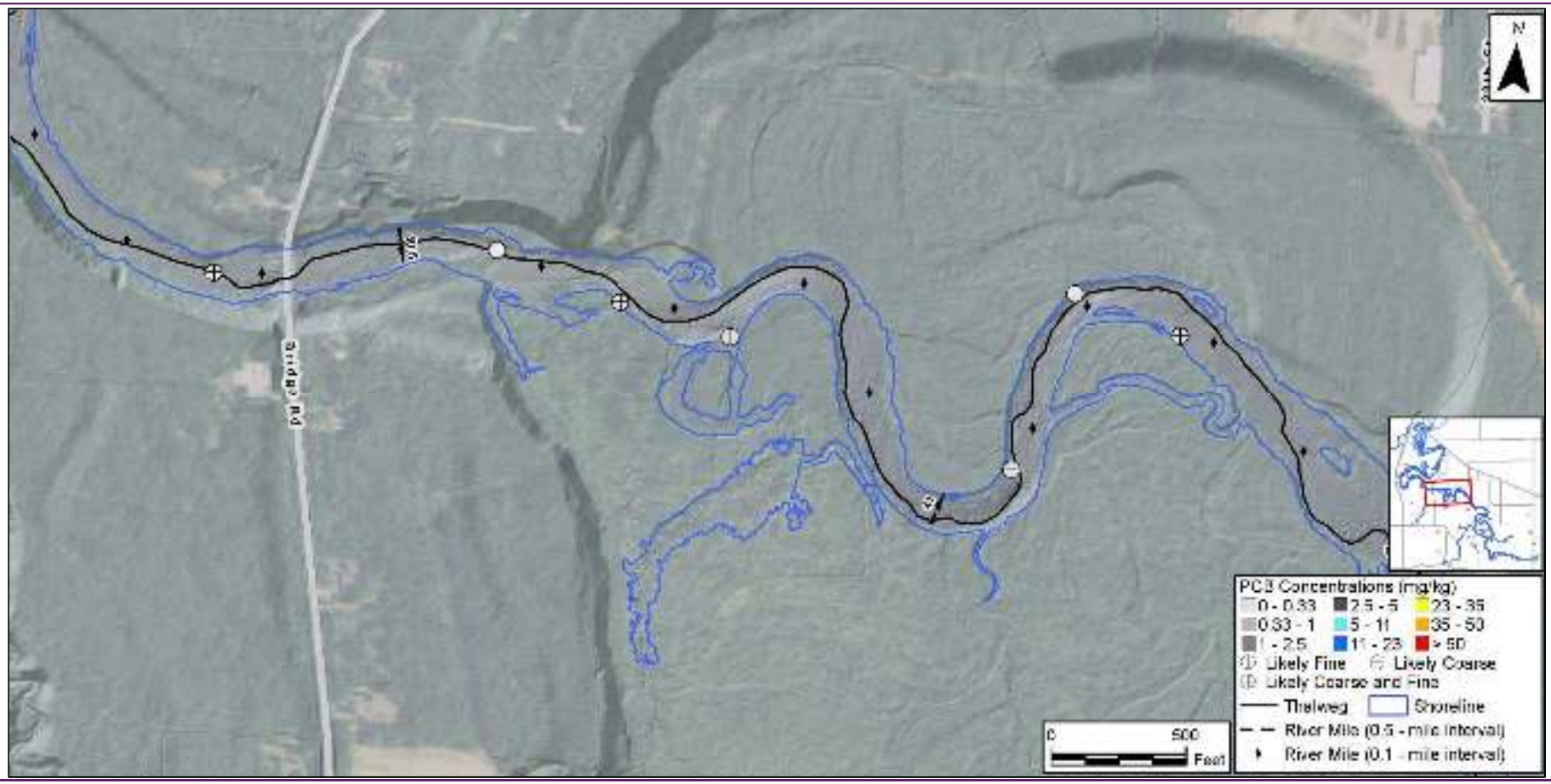
Recon II PCBs, Interval 1 – Channelized Flow



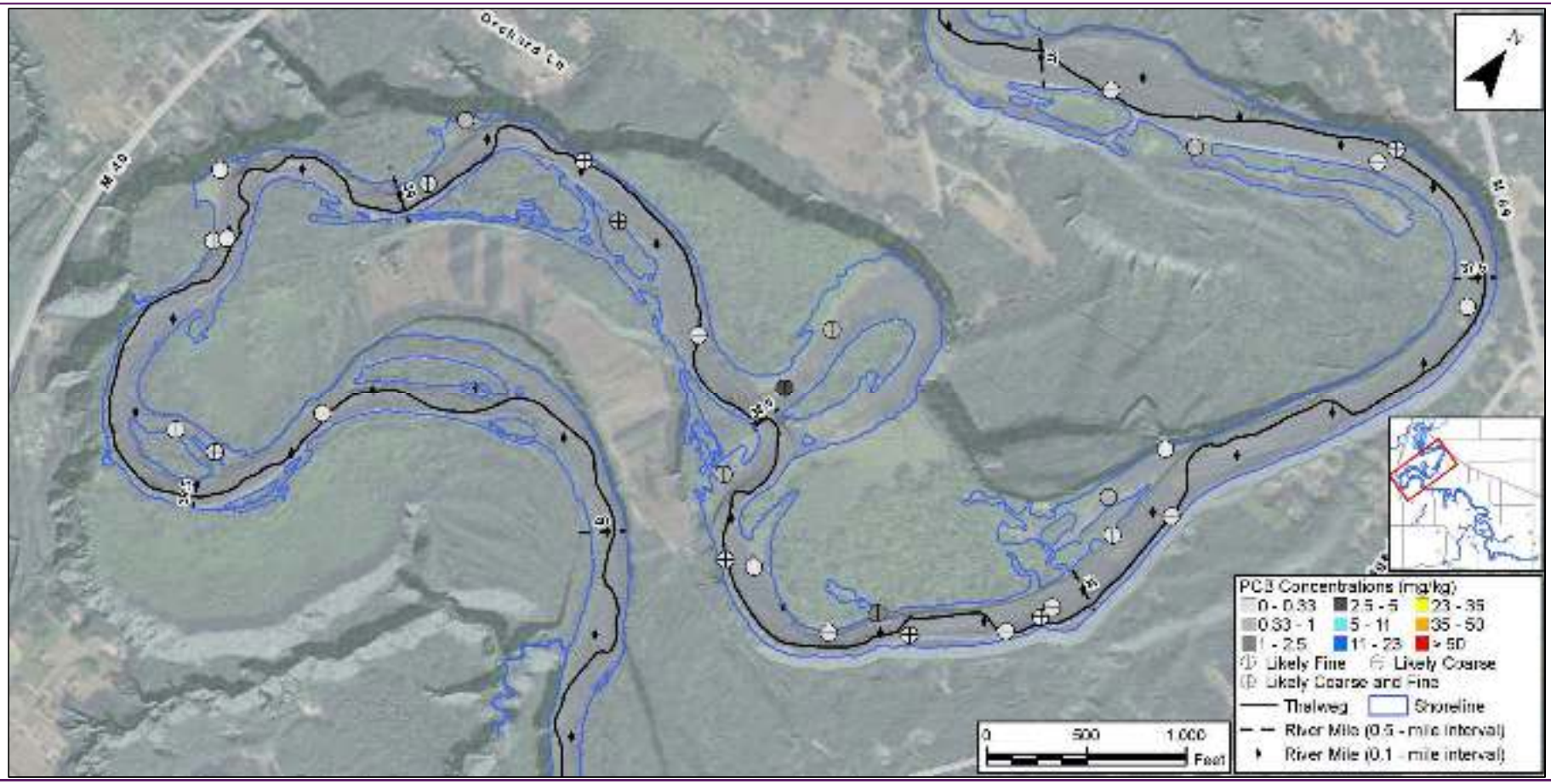
Recon II PCBs, Interval 2 – Channelized Flow



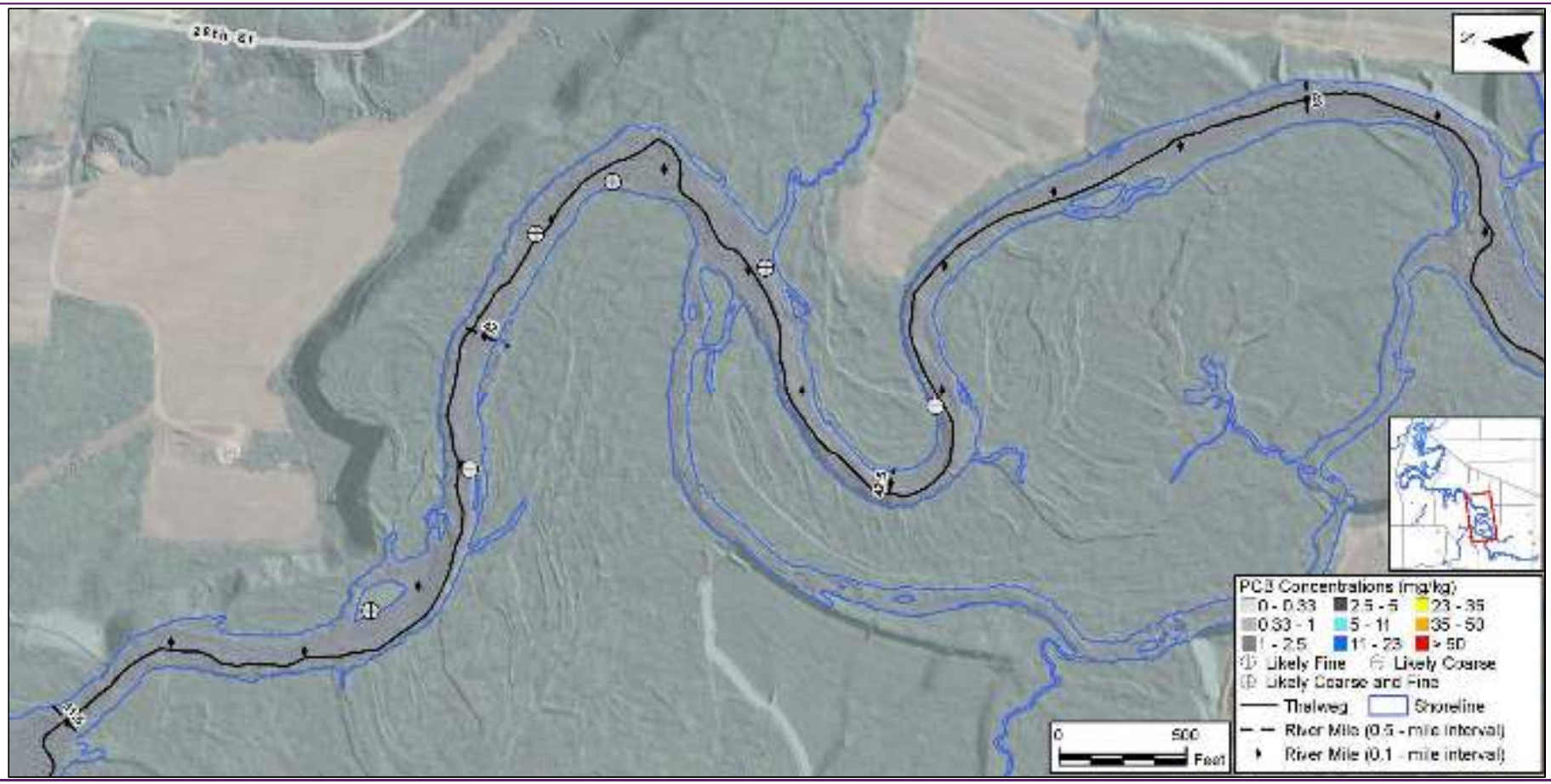
Recon II PCBs, Interval 2 – Channelized Flow



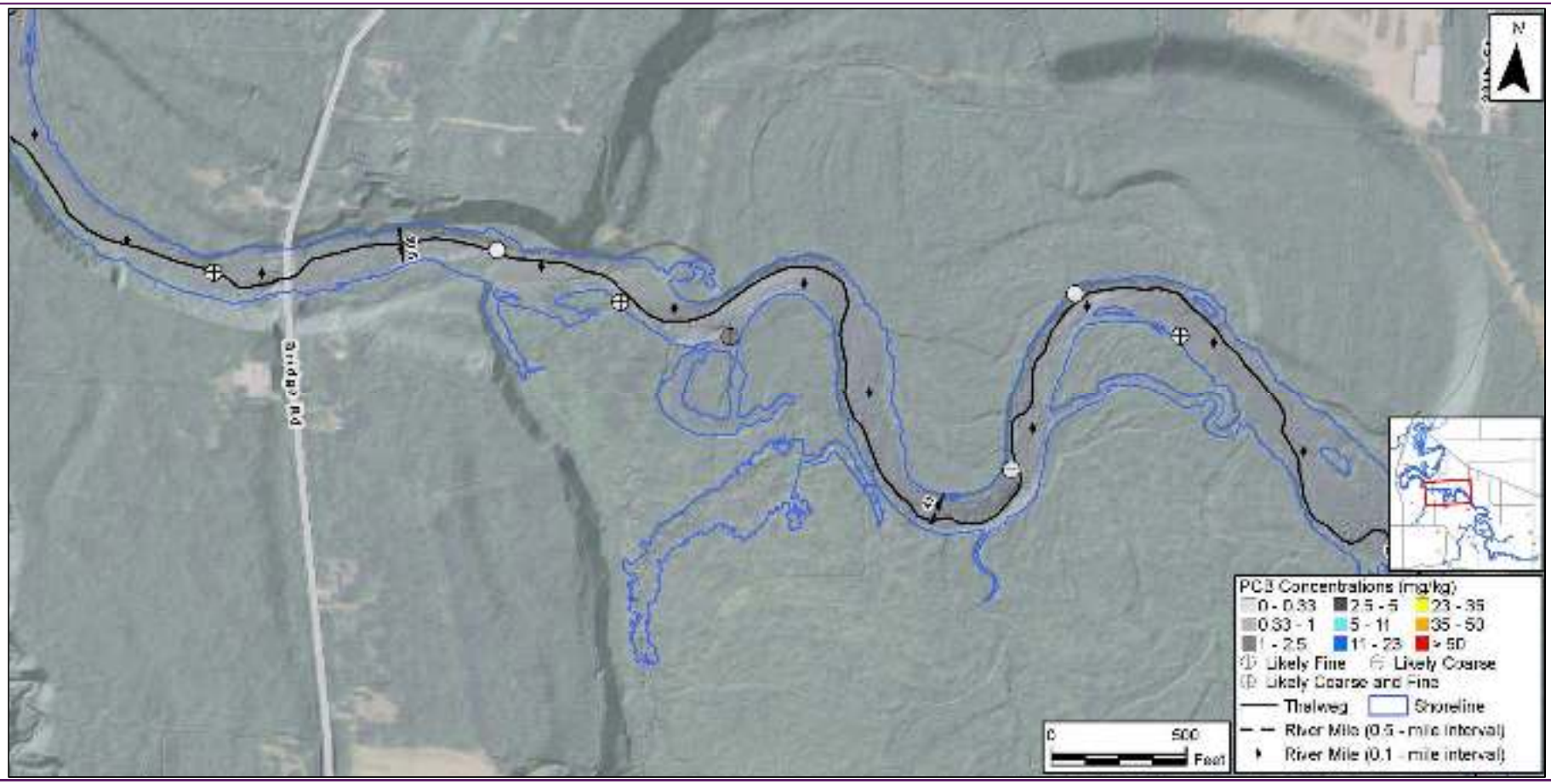
Recon II PCBs, Interval 2 – Channelized Flow



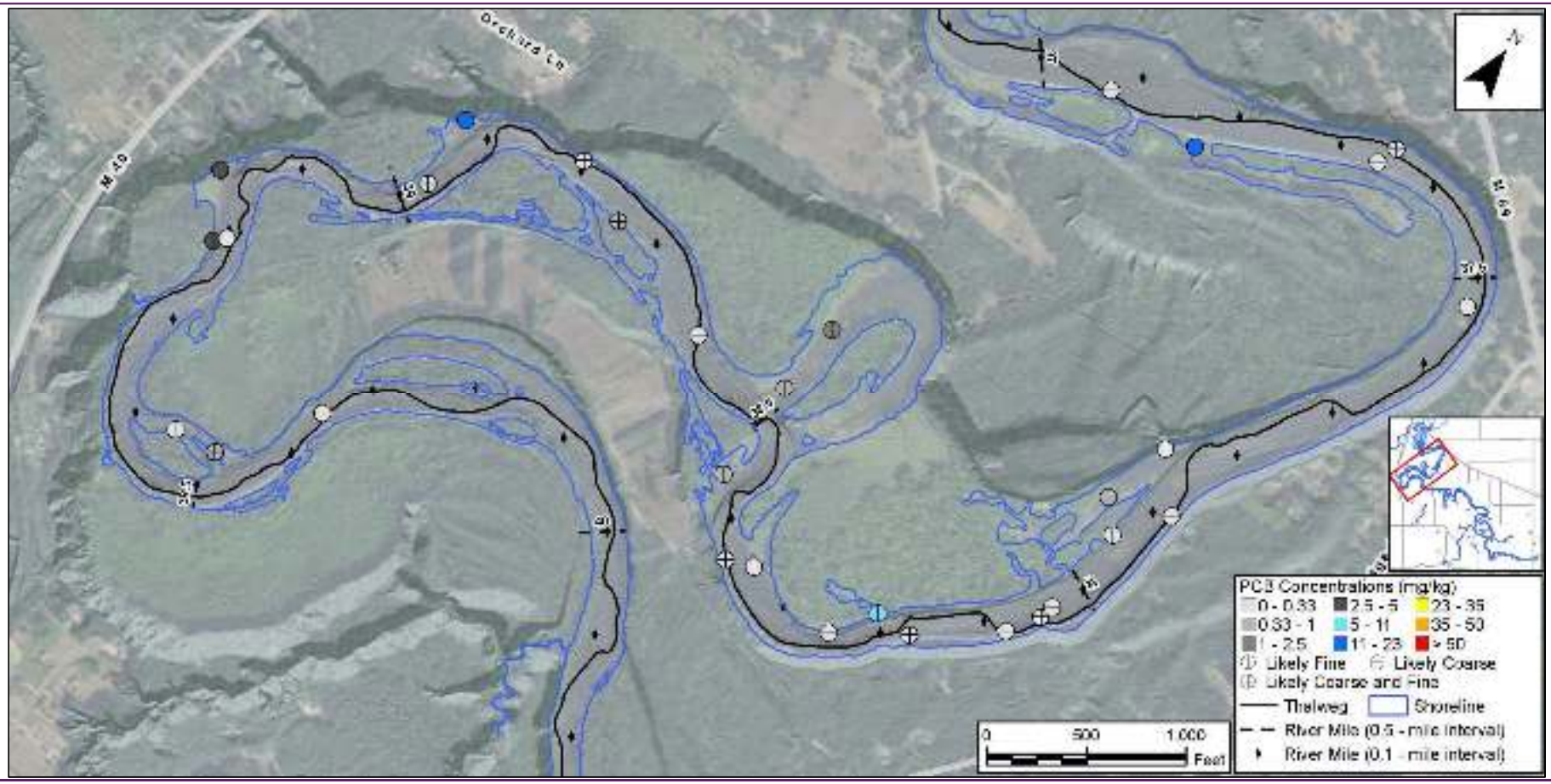
Recon II PCBs, Interval 3 – Channelized Flow



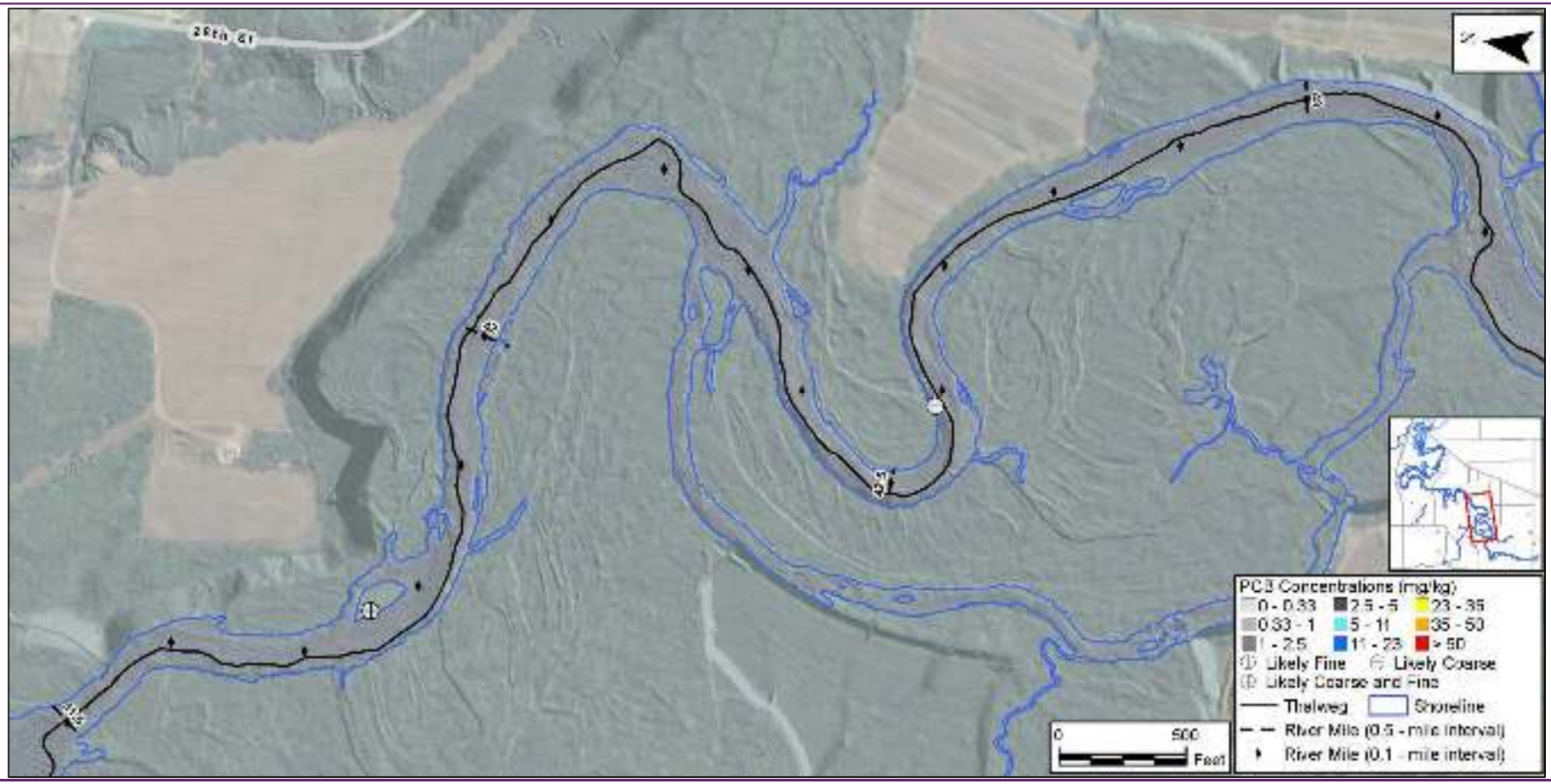
Recon II PCBs, Interval 3 – Channelized Flow



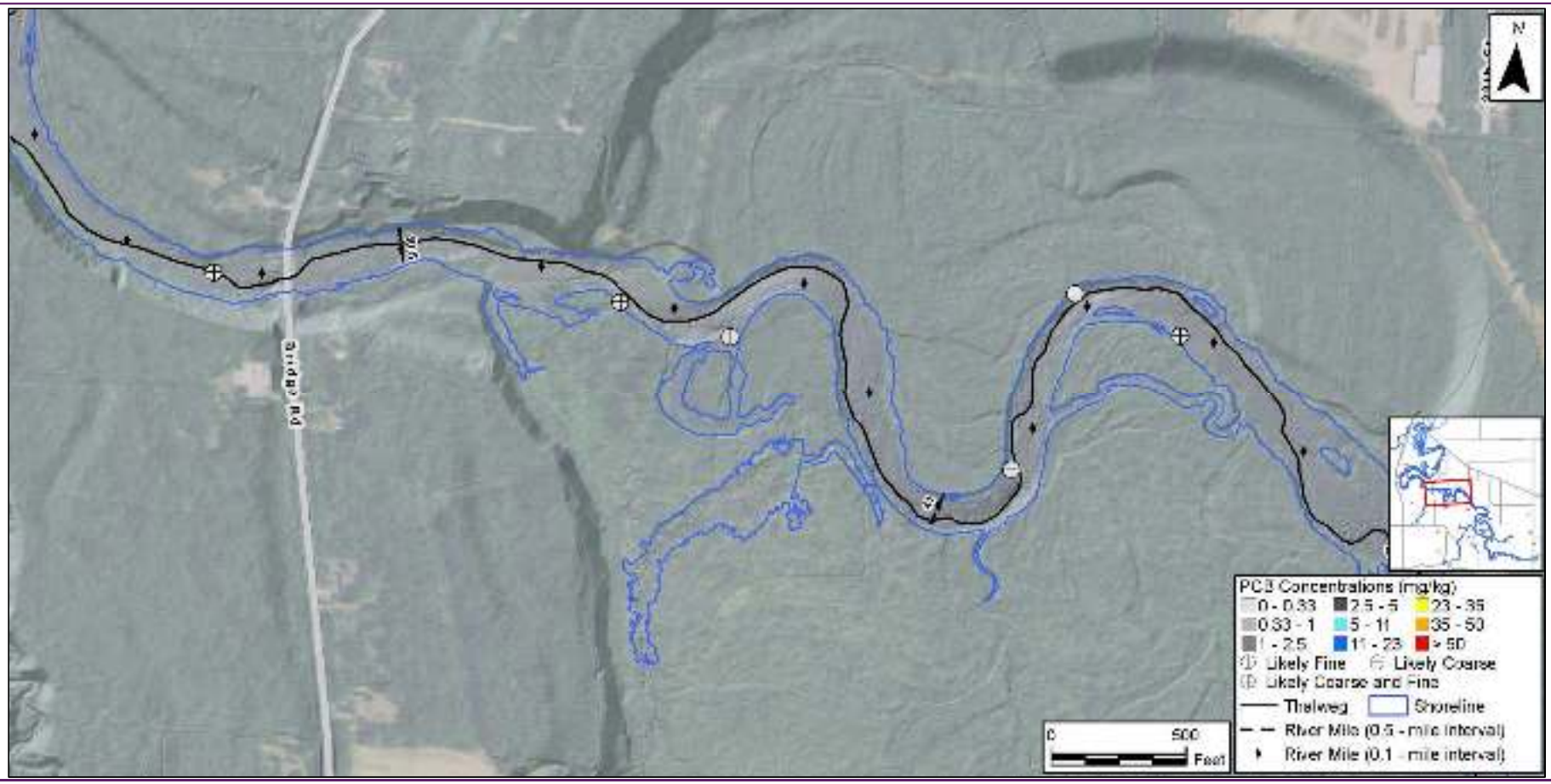
Recon II PCBs, Interval 3 – Channelized Flow



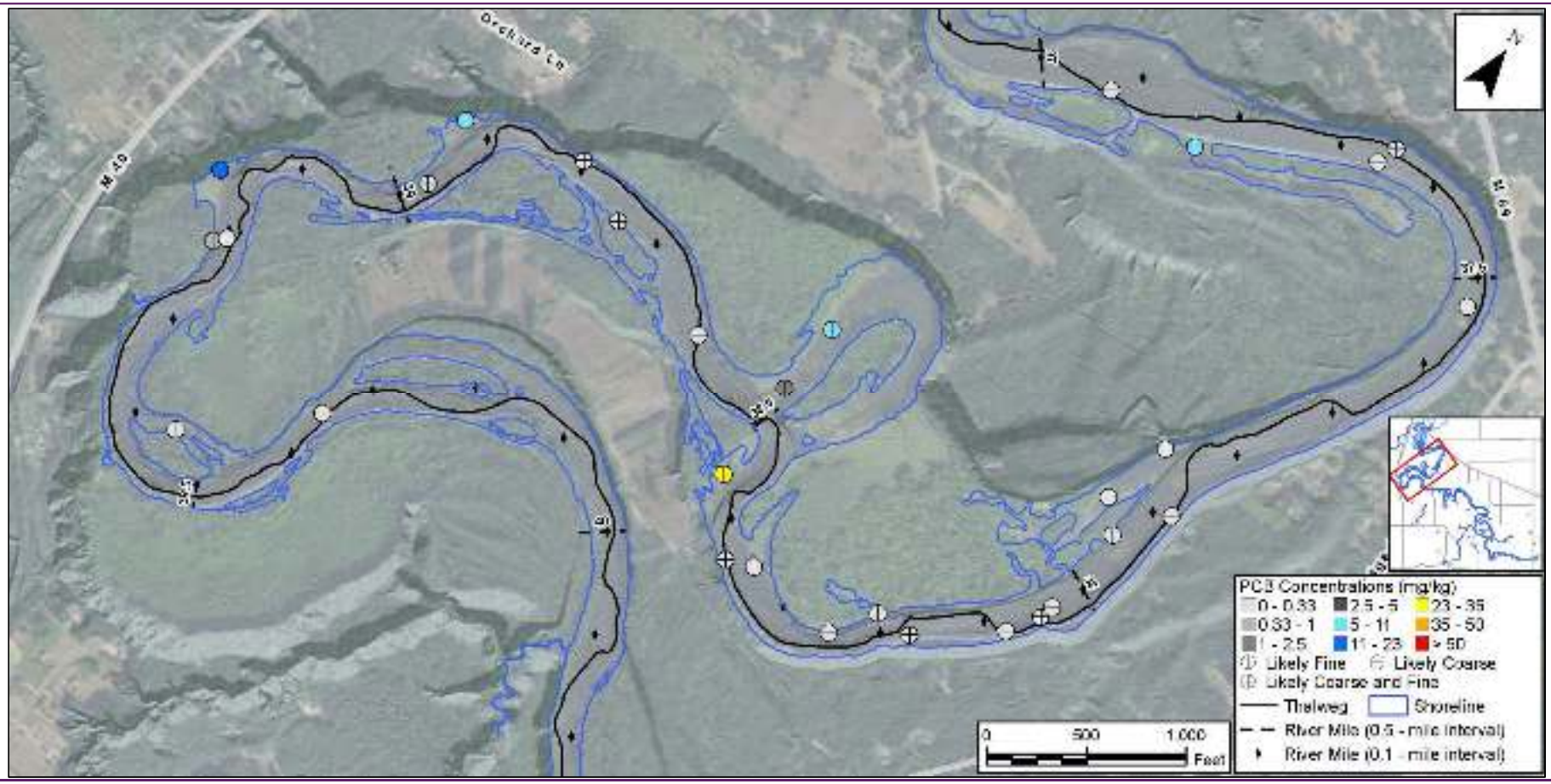
Recon II PCBs, Interval 4 – Channelized Flow



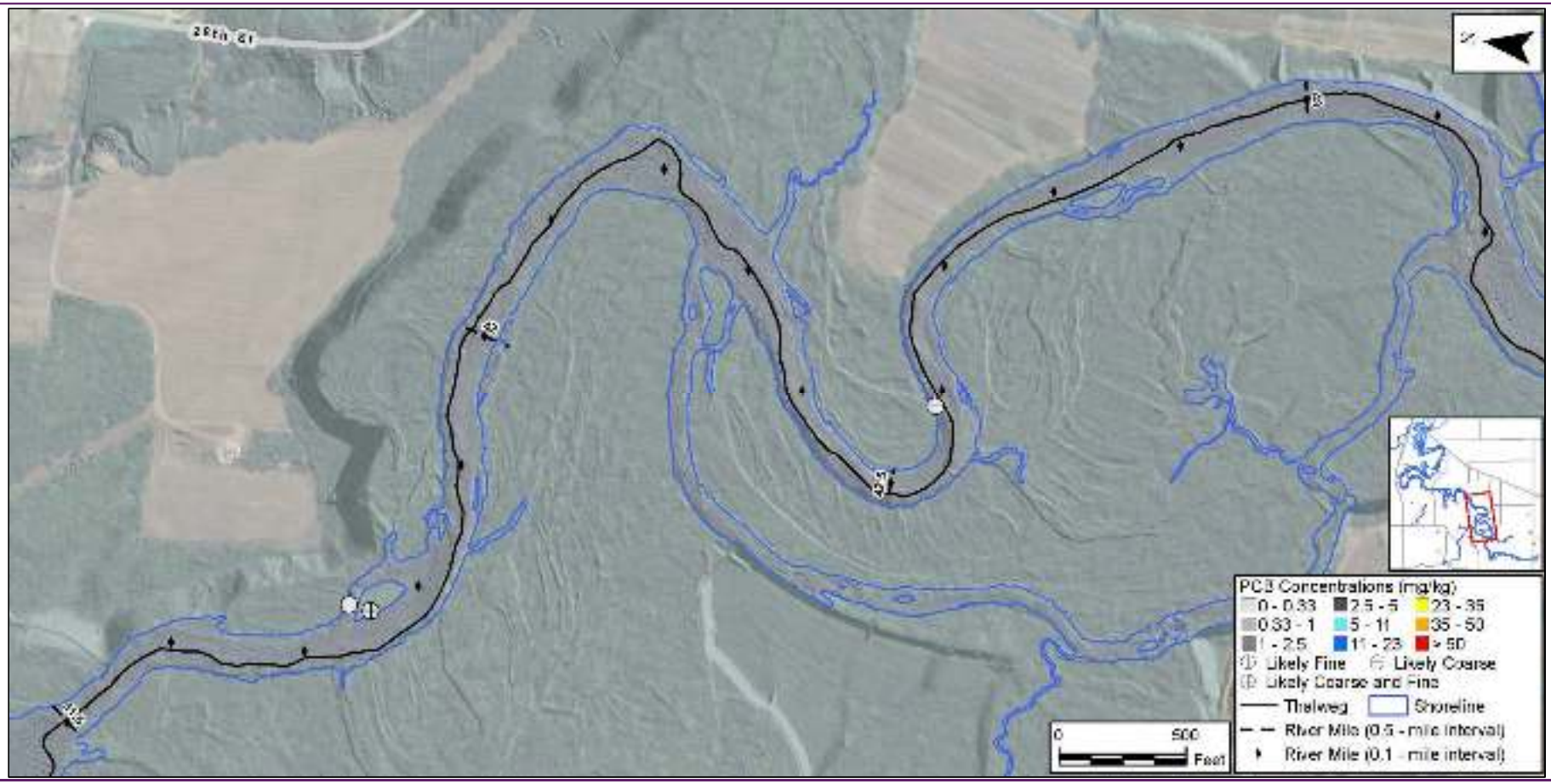
Recon II PCBs, Interval 4 – Channelized Flow



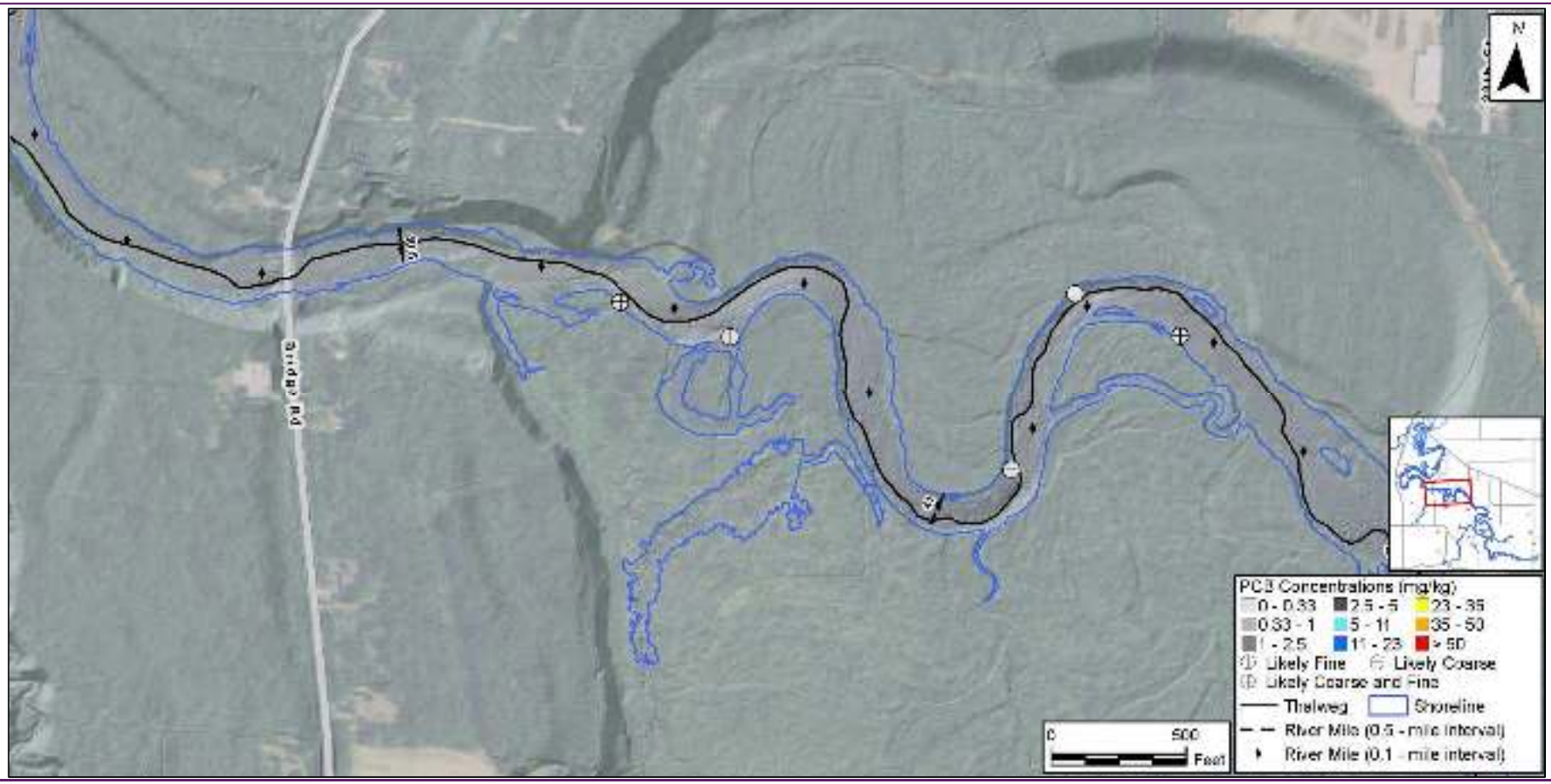
Recon II PCBs, Interval 4 – Channelized Flow



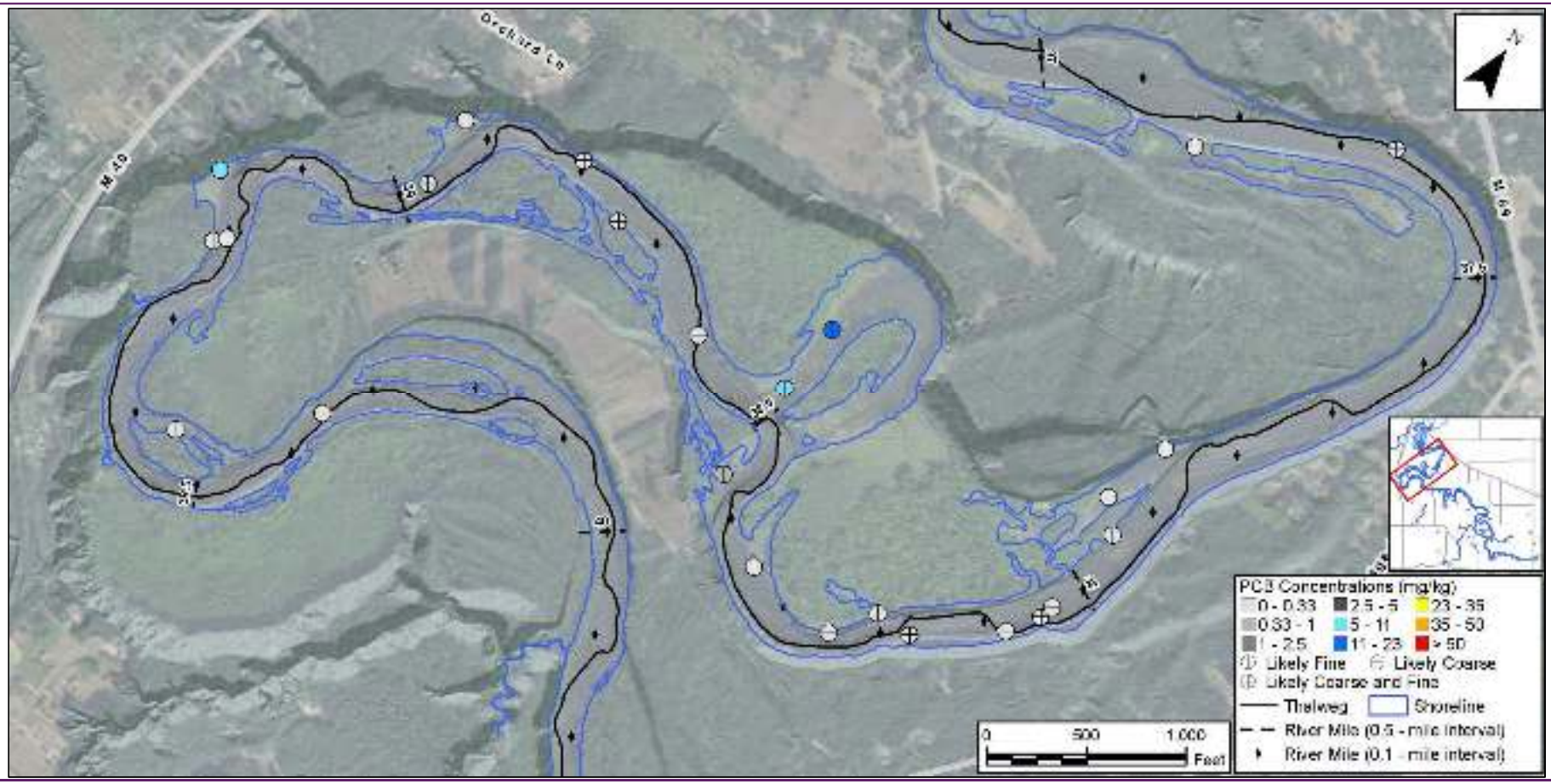
Recon II PCBs, Interval 5 – Channelized Flow



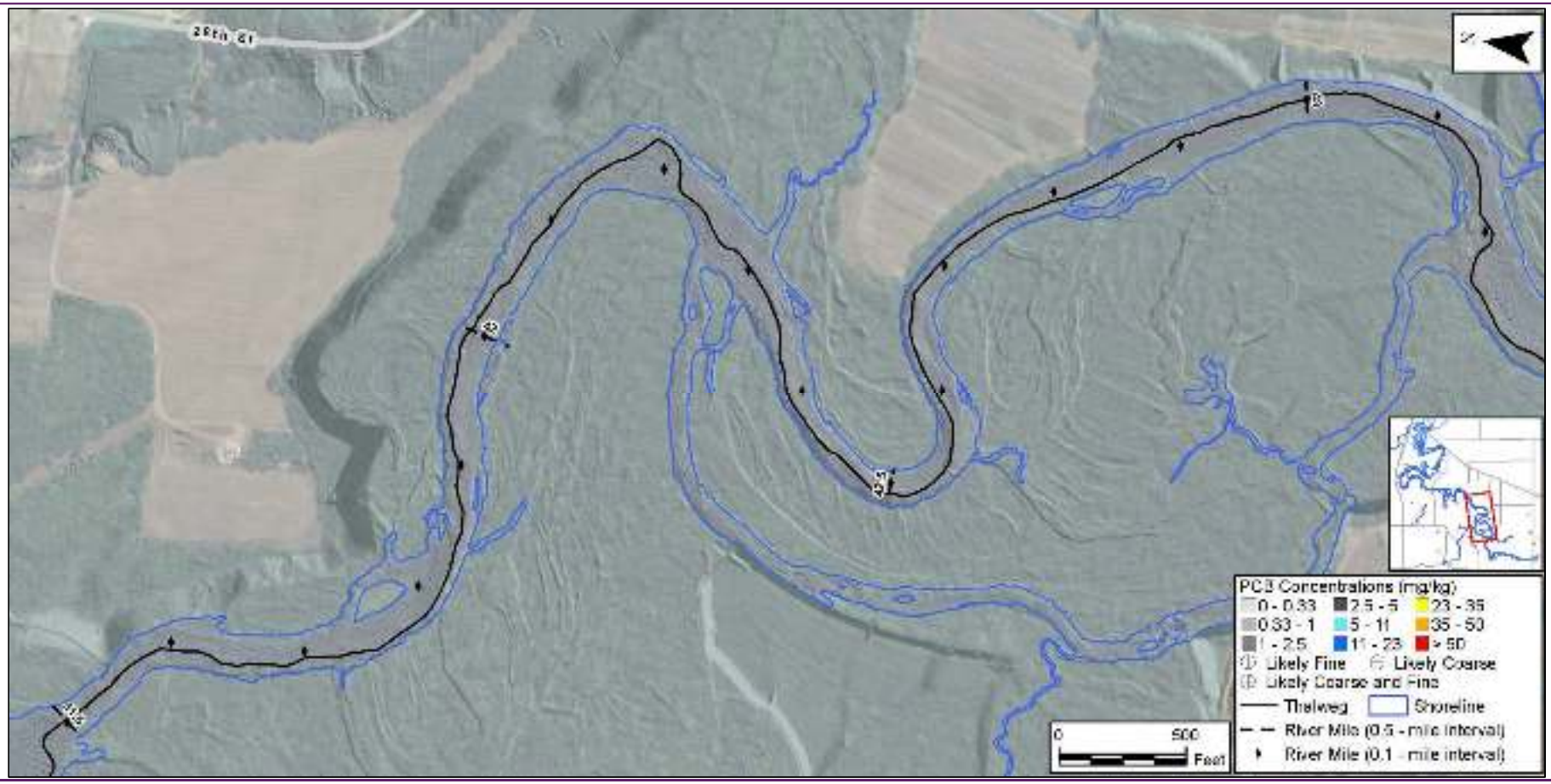
Recon II PCBs, Interval 5 – Channelized Flow



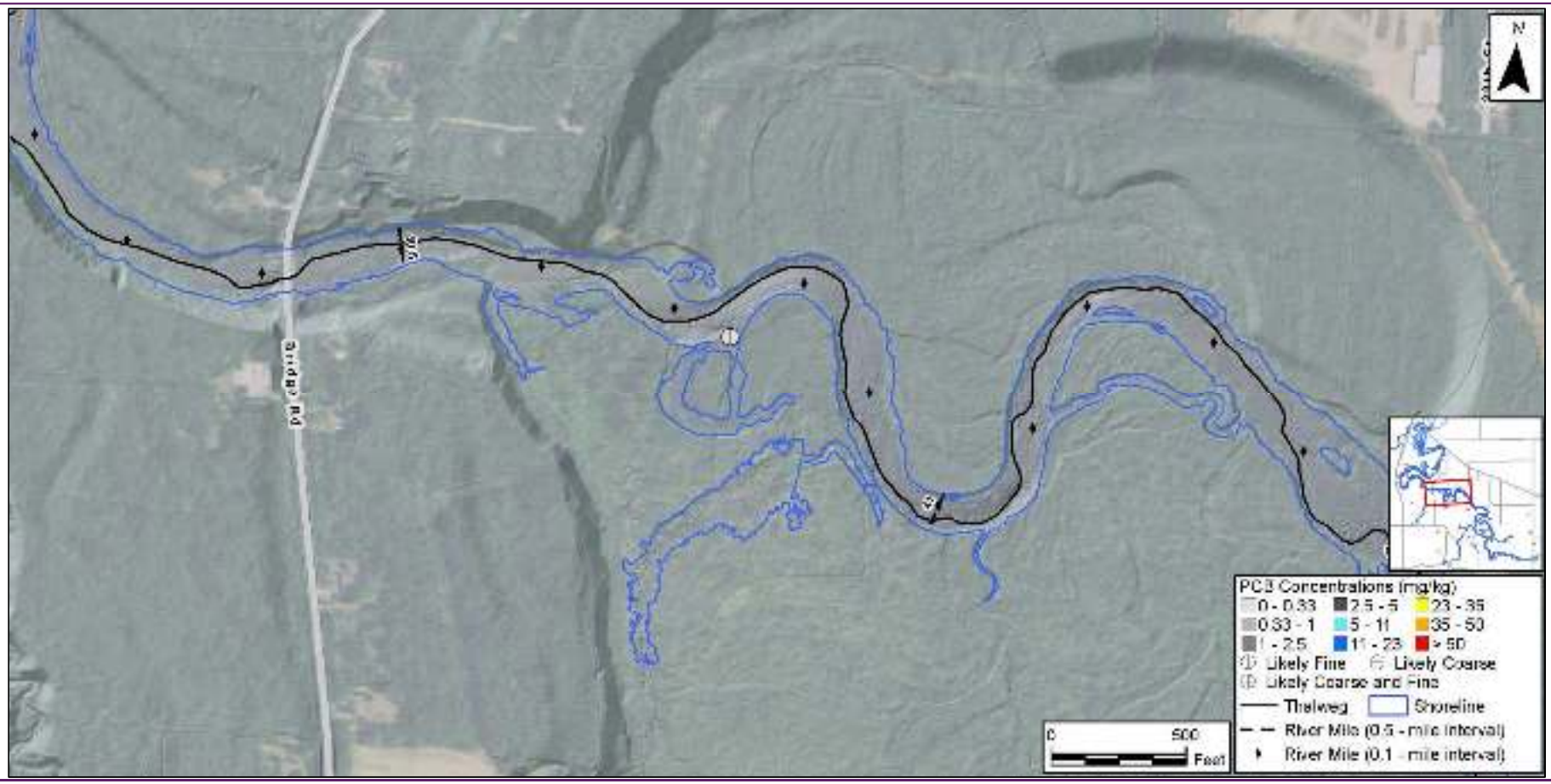
Recon II PCBs, Interval 5 – Channelized Flow



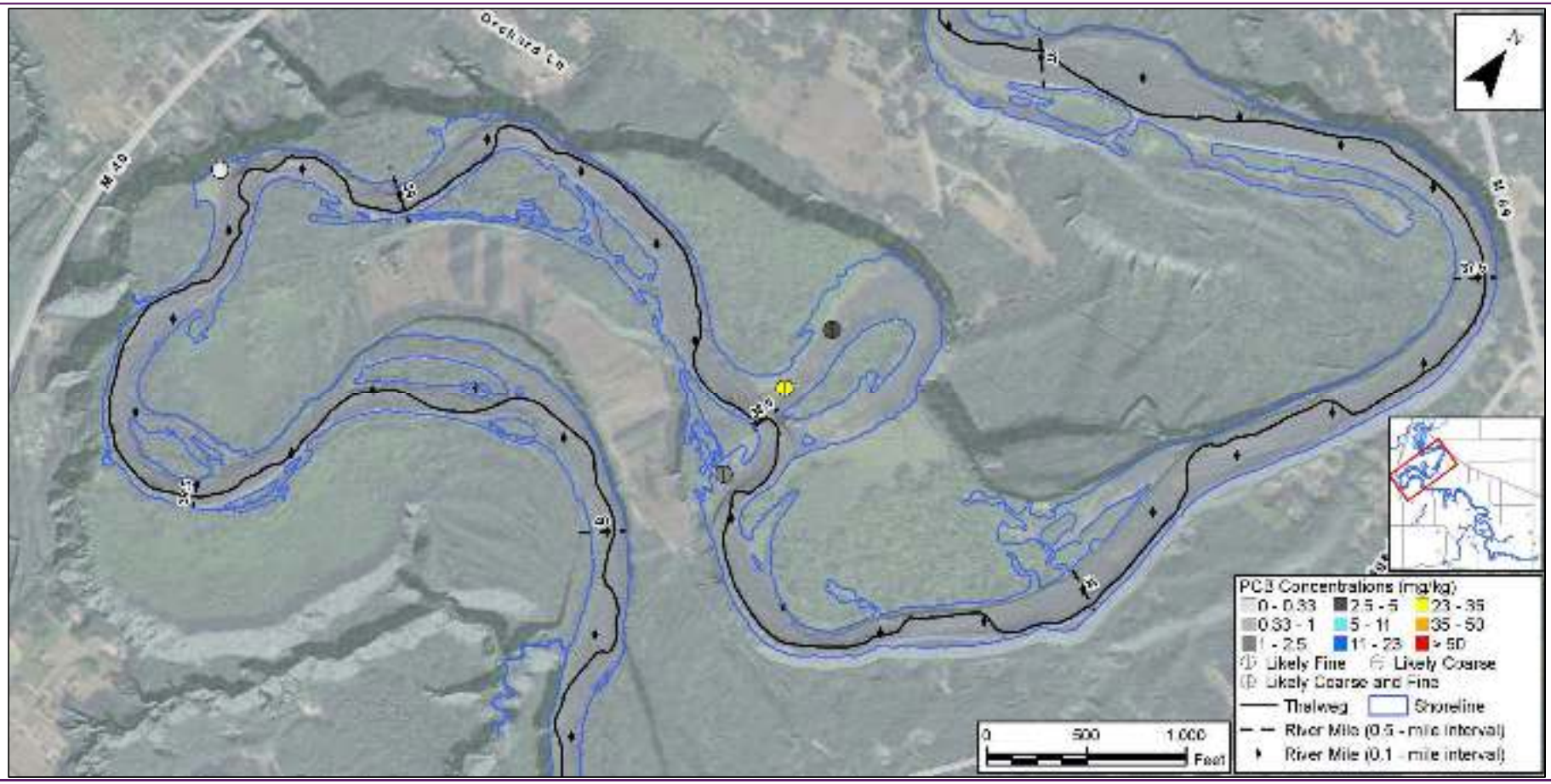
Recon II PCBs, Interval 6 – Channelized Flow



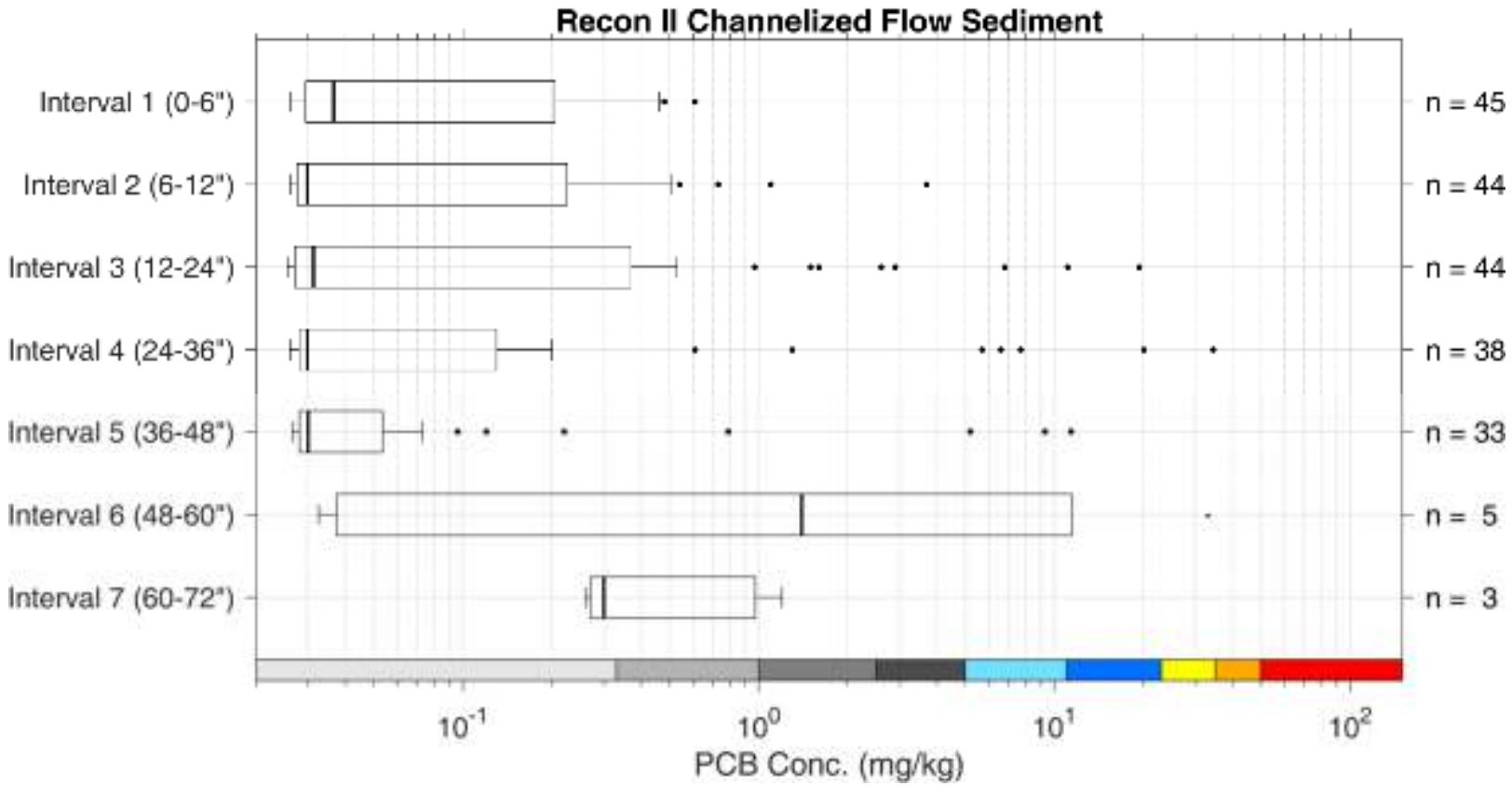
Recon II PCBs, Interval 6 – Channelized Flow



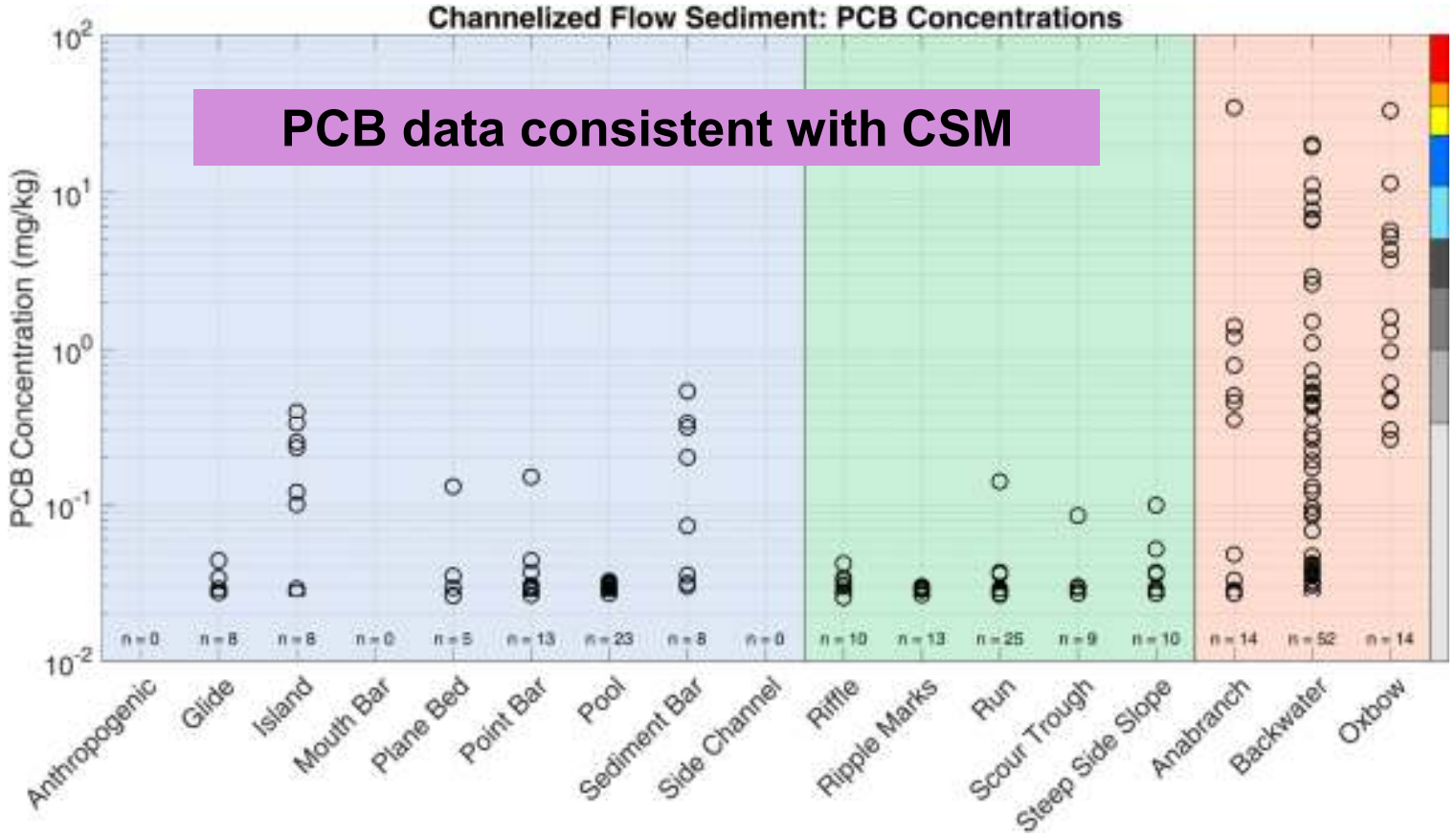
Recon II PCBs, Interval 6 – Channelized Flow



PCB Distributions by Depth



PCB Distributions by Depth



Channelized Flow Sediments

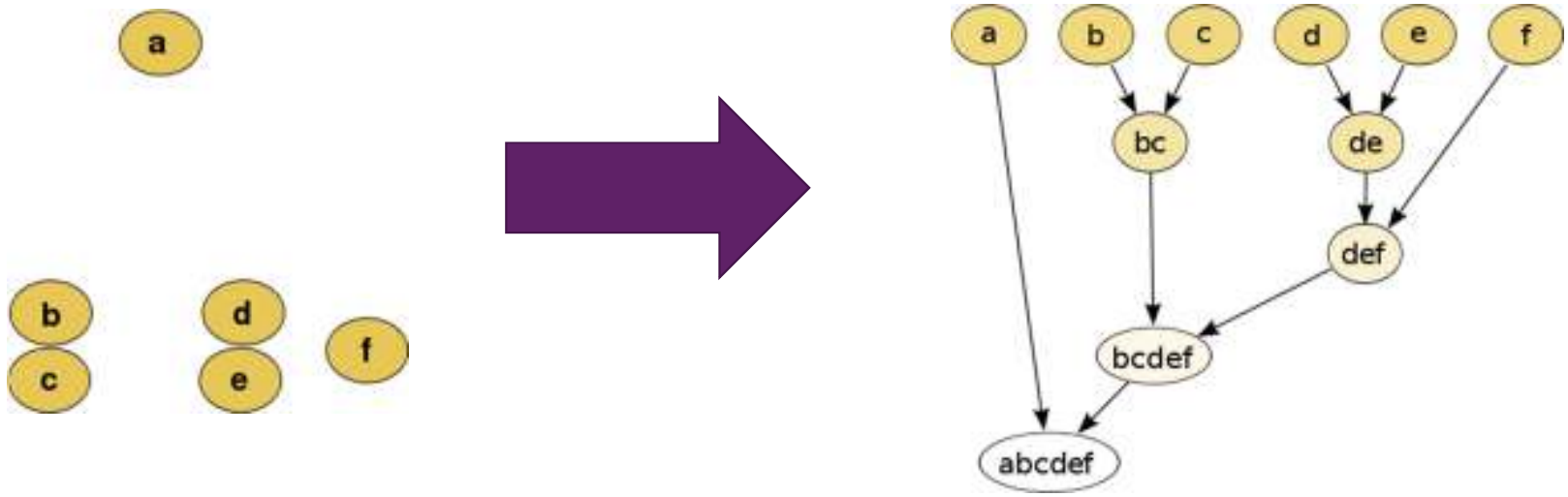
Cluster Analysis – A method of bedform categorization

Grouping of bedforms and selecting sample density

Cluster Analysis

Cluster analysis is a statistical process of grouping data such that data within a group are more similar to each other than those in other groups.

Objective: Simplify complex multivariate sediment data into consistent groups or strata.



Channelized Flow Multivariate Data

Data used in cluster analysis

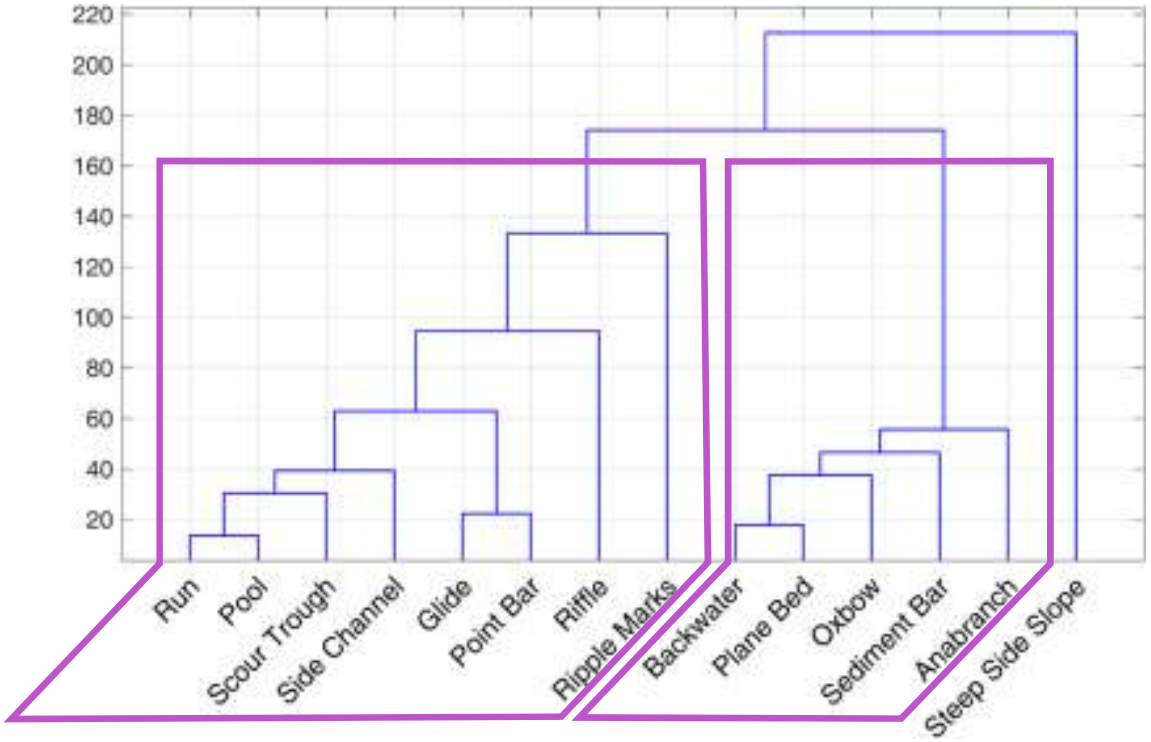
- Sediment thickness
- Surface gradation
  - Percent fines
  - Percent fine sand
  - Percent medium sand
  - Percent coarse sand or greater
- Hydrodynamic Model Results (1100, 3200, 4900, 8400, 12000 cfs)
  - WSE
  - Water depth
  - Velocity
  - Shear stress

Data not used in cluster analysis

- PCB concentrations
- Bathymetry and derivatives (e.g., slope, aspect, curvature)

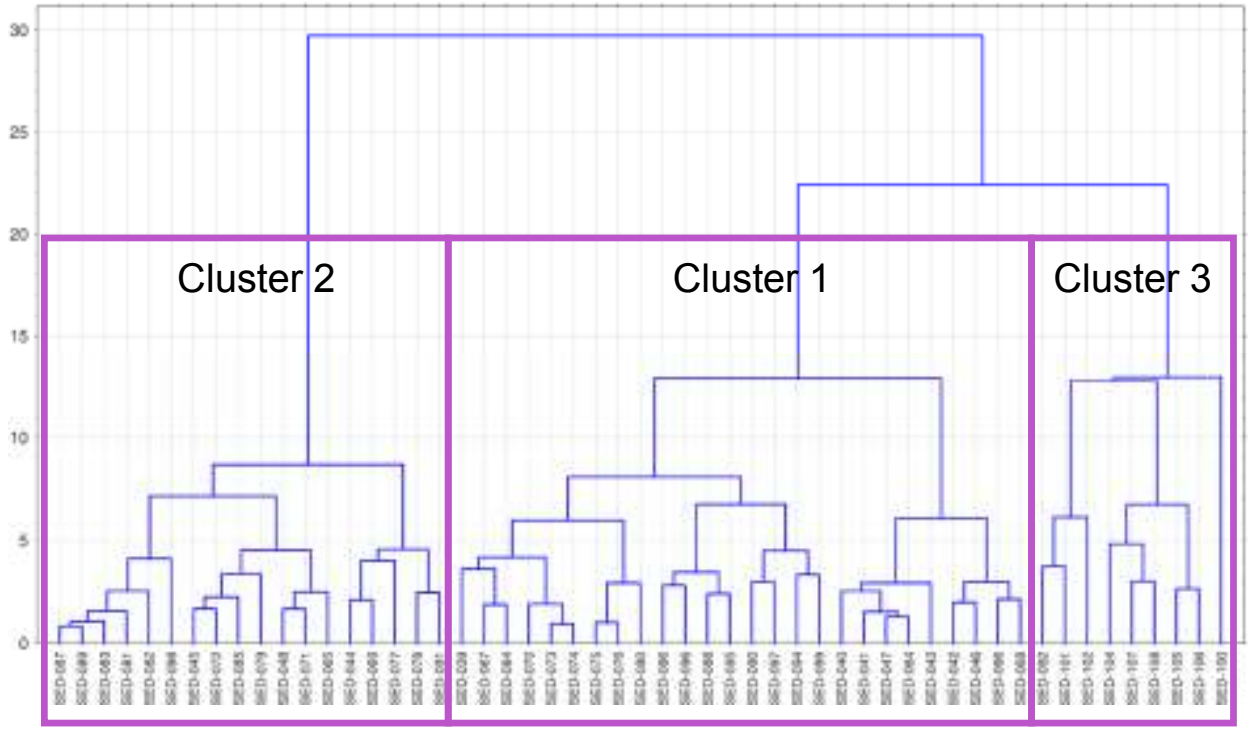
Multivariate Analysis of Variance

How do the geomorphic features cluster into broader groups?



- Similar to ANOVA, but with multiple categorical groups
- Clusters based on multivariate means, sensitive to outliers
- Two main clusters
  - Lower velocity, thicker sediment with more fines
  - Faster velocity, shallower sediment with coarse material
  - Steep Side Slope does not cluster in either group

Individual Sample Hierarchical Cluster Analysis



	Cluster 2	Cluster 1 & 3
Steep Side Slope	1	1
Side Channel	1	1
Sediment Bar	1	1
Scour Trough	0	2
Run	0	12
Ripple Marks	0	3
Riffle	0	2
Pool	0	5
Point Bar	0	3
Plane Bed	1	1
Oxbow	2	0
Mouth Bar	0	0
Island	0	0
Glide	0	2
Backwater	11	0
Anabranch	1	2

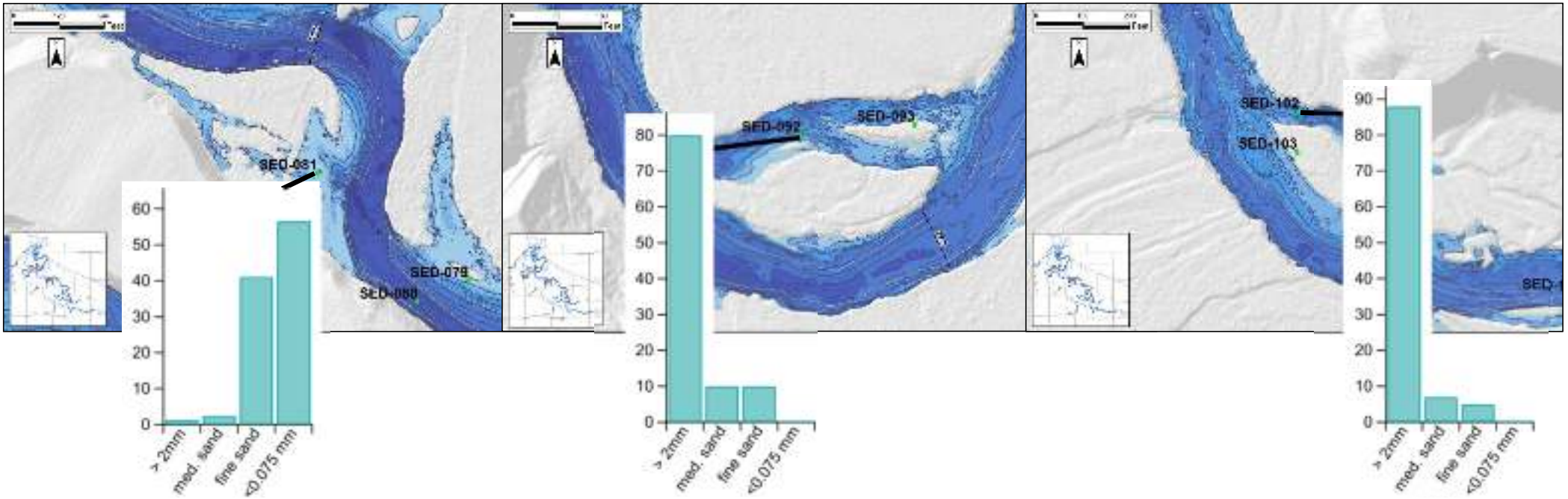
Using Results of Cluster Analysis

If we want to use the Cluster groups for the Phase I stratified random sampling design, we need to know how to properly place individual bedforms into a cluster that fell into both clusters.

- Cluster analysis is sensitive to outlier data
- Bedform boundaries could be modified slightly, reassigning sediment cores to new bedforms
  - Steep Side Slope: SED-078 & SED-100
  - Side Channel: SED-039 & SED-044
  - Sediment Bar: SED-085 & SED-107
  - Plane Bed: SED-048 & SED-088
  - Anabranch: SED-081, SED-092, & SED-102

	Cluster 2	Cluster 1 & 3
Steep Side Slope	1	1
Side Channel	1	1
Sediment Bar	1	1
Scour Trough	0	2
Run	0	12
Ripple Marks	0	3
Riffle	0	2
Pool	0	5
Point Bar	0	3
Plane Bed	1	1
Oxbow	2	0
Mouth Bar	0	0
Island	0	0
Glide	0	2
Backwater	11	0
Anabranch	1	2

Anabranch Bedform: SED-081, SED-092, & SED-102



SED-081

Reassigned Backwater

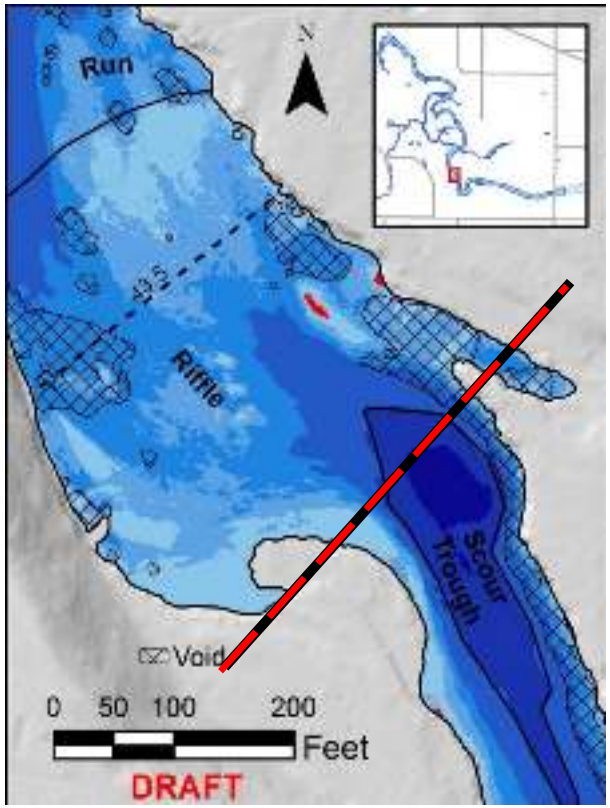
SED-092

Reassigned to Run

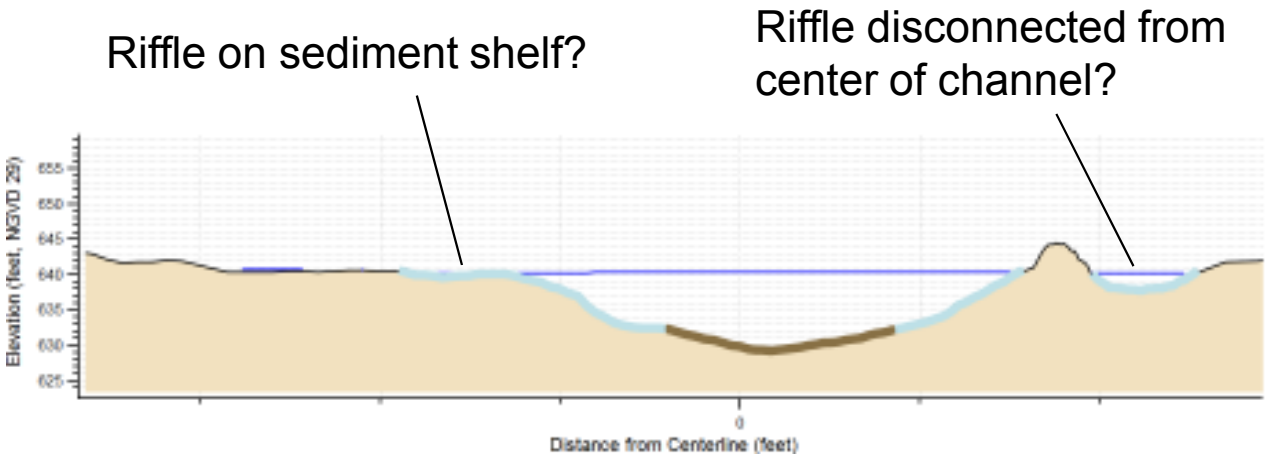
SED-102

Reassigned to Scour Trough

Bedform Edits

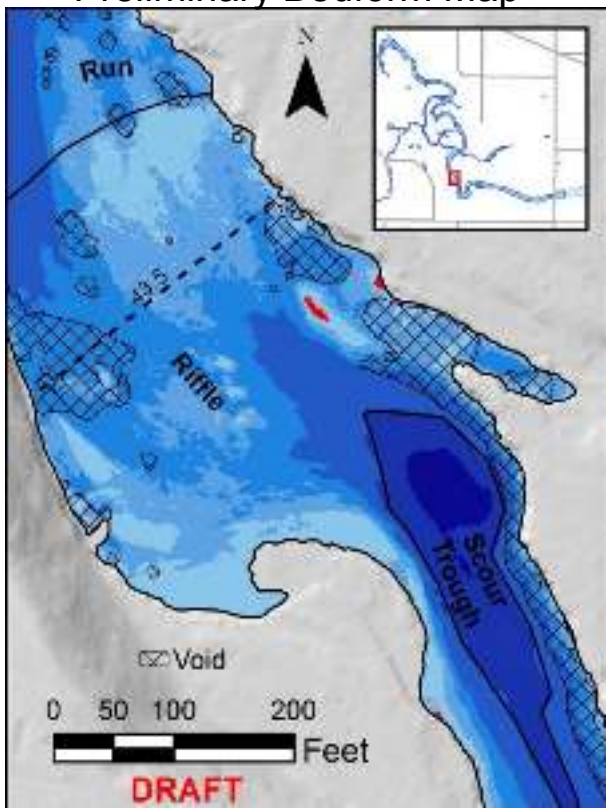


- Made by using the cross-section tool and terrain attributes
- Main edits include
  - Anabranches
  - Steep Side Slopes

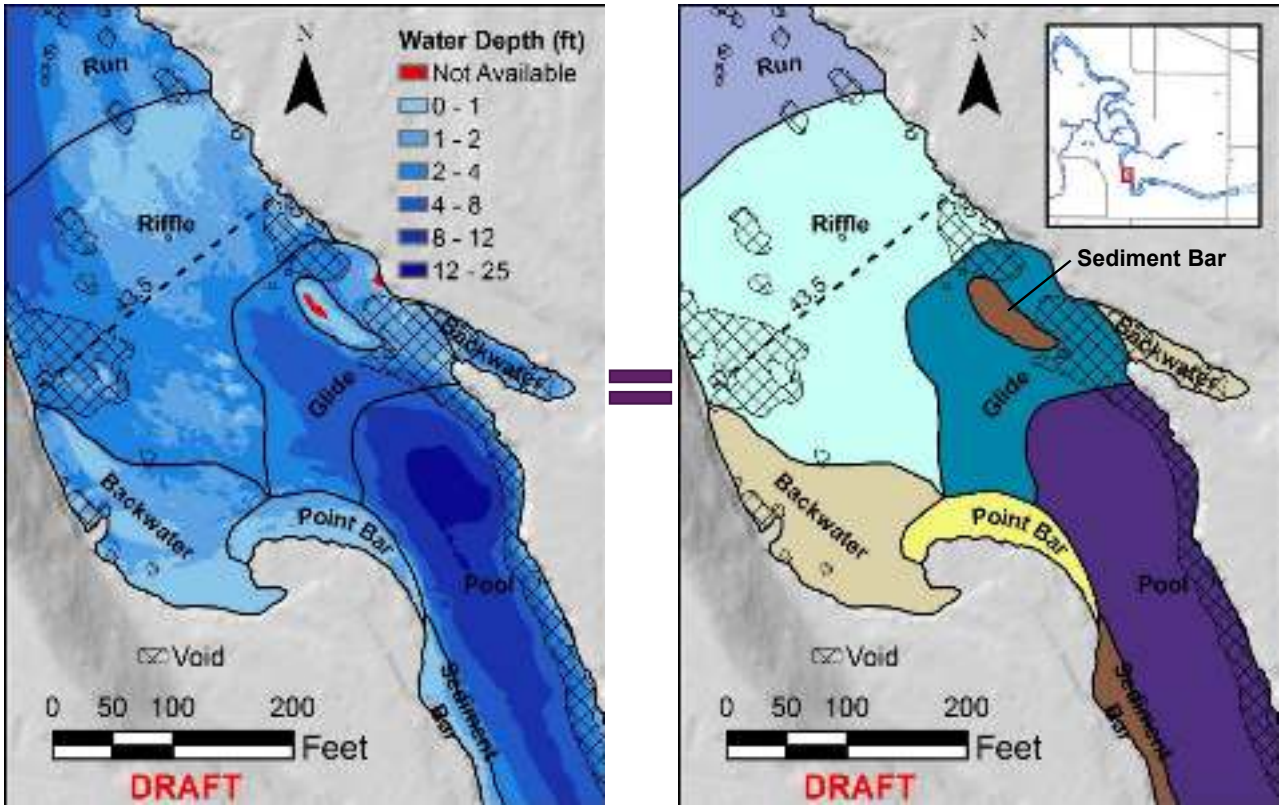


Bedform Edits

Preliminary Bedform Map



Revised Bedform Map



Effect of Bedform Revisions on Cluster Analysis Interpretation

Original bedform definition

	Cluster 2	Cluster 1 & 3
Steep Side Slope	1	1
Side Channel	1	1
Sediment Bar	1	1
Scour Trough	0	2
Run	0	12
Ripple Marks	0	3
Riffle	0	2
Pool	0	5
Point Bar	0	3
Plane Bed	1	1
Oxbow	2	0
Mouth Bar	0	0
Island	0	0
Glide	0	2
Backwater	11	0
Anabranch	1	2

Simpler

Revised bedform definition

	Cluster 2	Cluster 1 & 3
Steep Side Slope	0	0
Side Channel	1	0
Sediment Bar	1	1
Scour Trough	0	4
Run	0	11
Ripple Marks	0	2
Riffle	0	2
Pool	0	10
Point Bar	2	2
Plane Bed	0	0
Oxbow	2	0
Mouth Bar	0	0
Island	0	0
Glide	0	3
Backwater	12	0
Anabranch	0	0

Using Results of Cluster Analysis to Design Sampling Strata

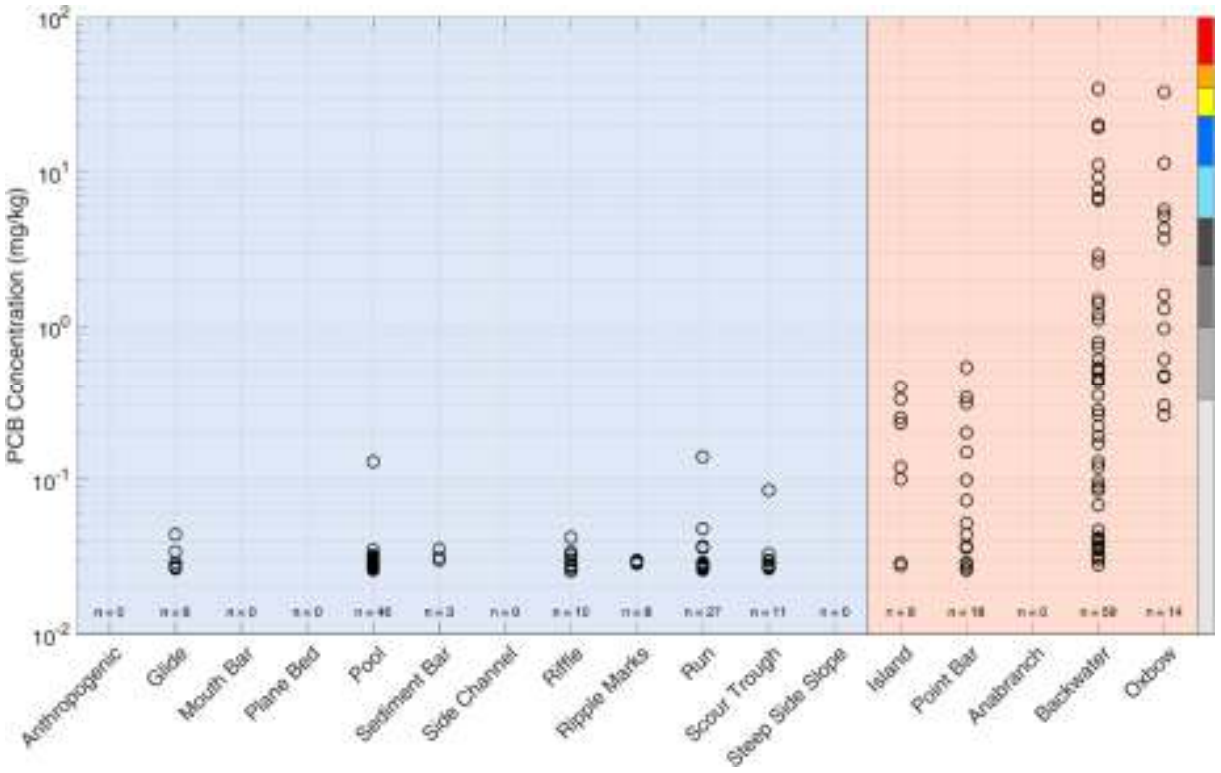
- Clusters 1 & 3 → Coarser Strata
- Cluster 2 → Finer Strata

Group 1	Group 2

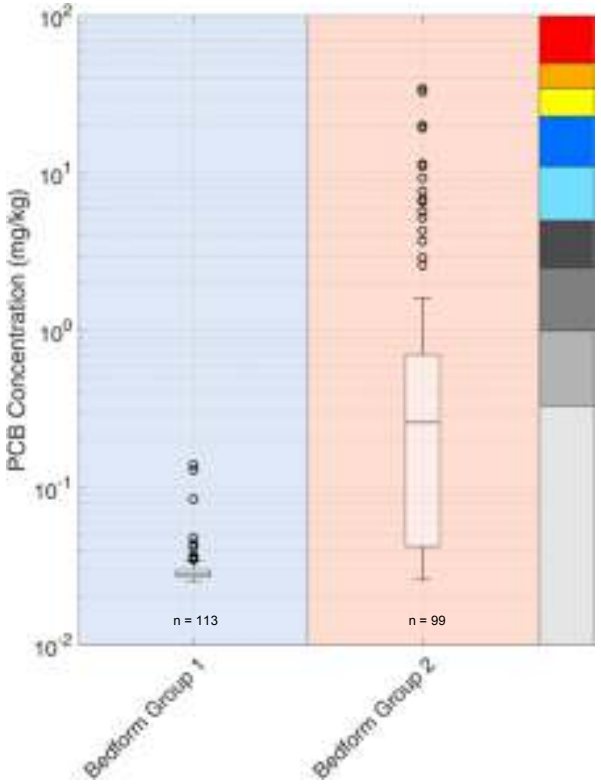
	Cluster 2	Cluster 1 & 3	
Steep Side Slope	0	0	
~~Side Channel~~	~~1~~	~~0~~	Impoundment
Sediment Bar	1	1	
Scour Trough	0	4	
Run	0	11	
Ripple Marks	0	2	
Riffle	0	2	
Pool	0	10	
Point Bar	2	2	
Plane Bed	0	0	
Oxbow	2	0	
~~Mouth Bar~~	~~0~~	~~0~~	Impoundment
Island	0	0	
Glide	0	3	
Backwater	12	0	
Anabranch	0	0	

PCB population statistics by Cluster

Individual Bedforms

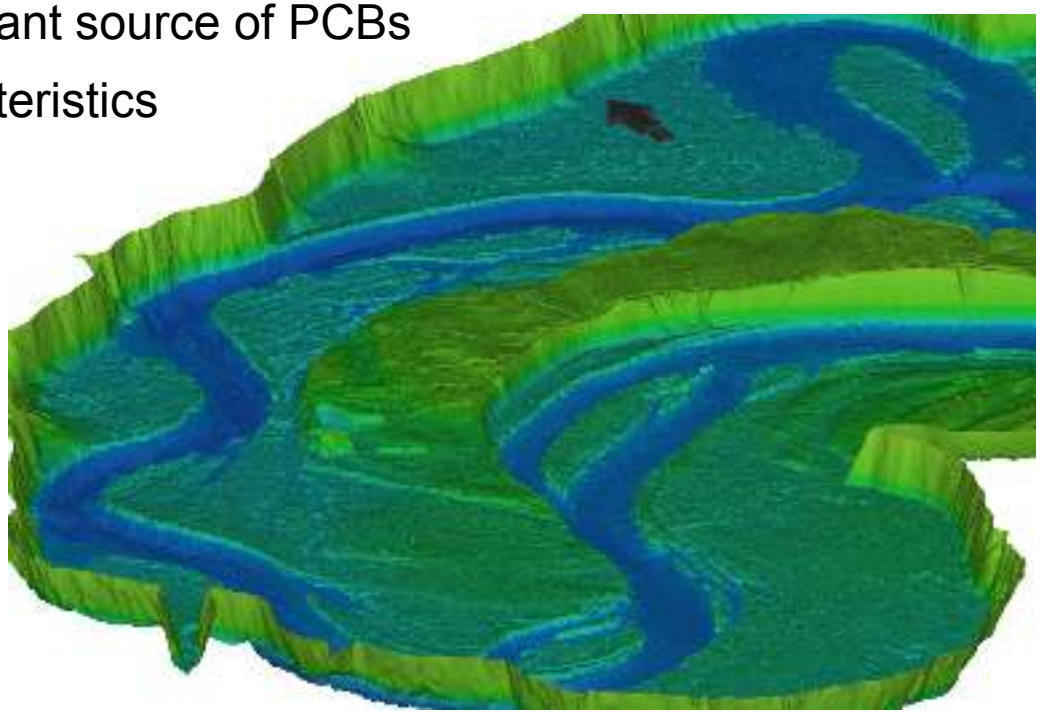


Bedform Strata



Area 5 Conceptual Site Model – Channelized Flow

- Historical aerials and glacial features suggest main channel is generally stable
- Lacks formerly impounded floodplains unlike Areas 1 through 4
- Bank soils are not likely to be a significant source of PCBs
- Bedforms predictive of physical characteristics and PCB concentrations



- Majority of bedforms with low PCB concentrations (156 of 221 acres with PCB conc. <0.33 mg/kg)
- Phase I Sampling should incorporate varying sample density based on two bedform groups

Stratified Random Sampling

- Used Neyman's optimal allocation in Visual Sample Plan (VSP, v 7.9)

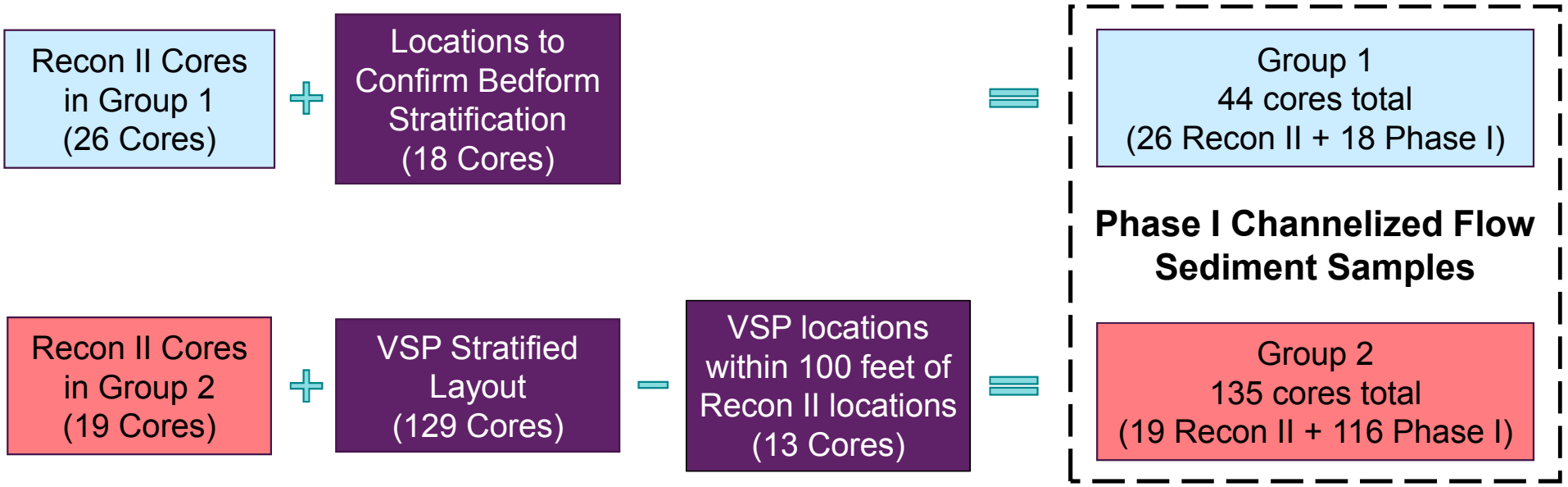
Strata	Recon II Samples			Phase I Cores
	N	Mean PCB (mg/kg)	Std Dev (mg/kg)	VSP Proposed Locations*
Group 1 (coarser)	113	0.03	0.02	0
Group 2 (finer)	99	2.11	5.74	129

*VSP proposed locations do not consider Recon II samples

- Minimum of 2 core locations per individual bedform class

Merging Recon II Samples with VSP

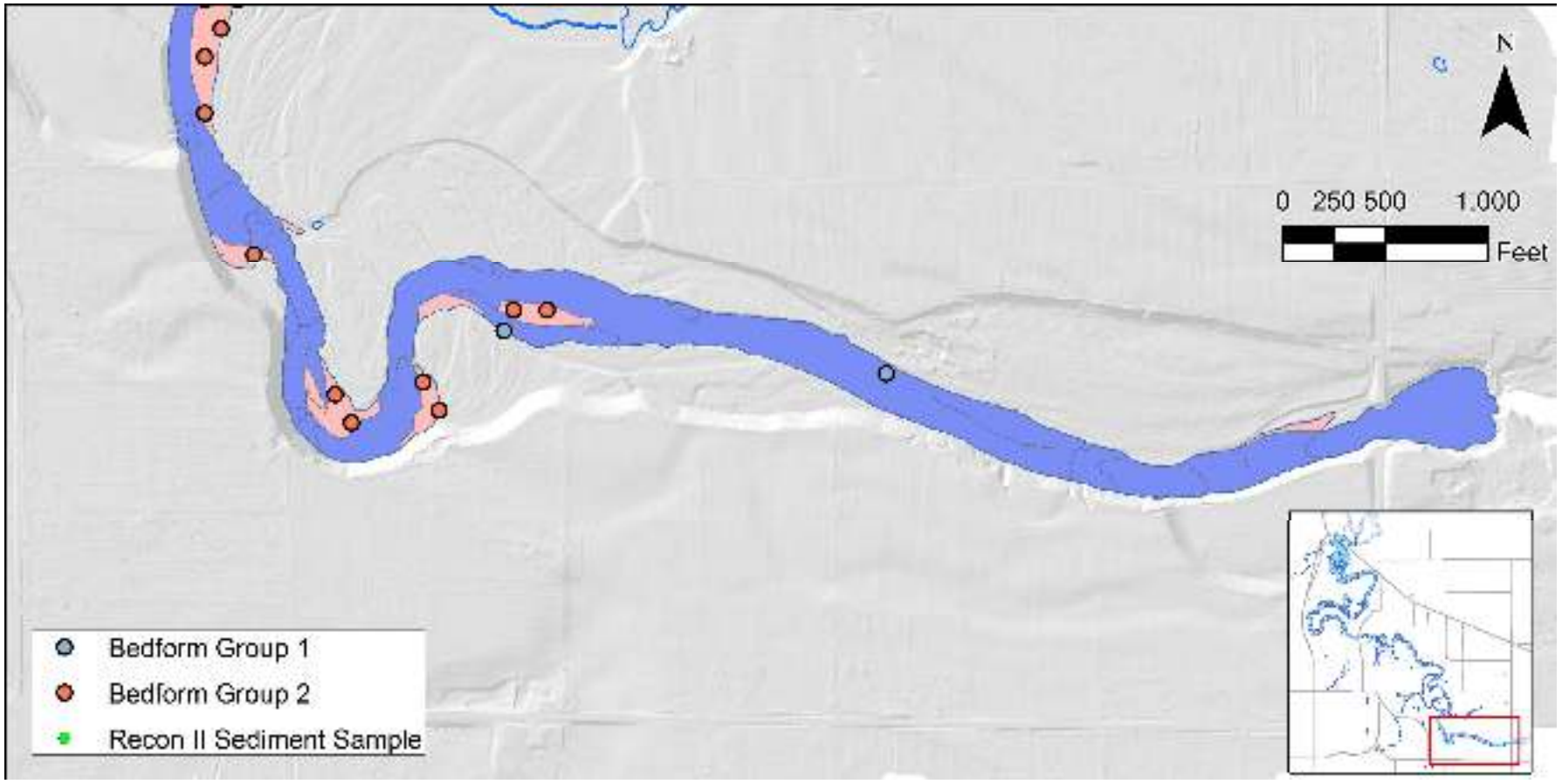
- 179 Cores Total in Channelized Flow
  - Recon II (45 cores)
  - VSP stratified layout (116 cores)
  - Locations to confirm bedform stratification (18 cores; 2 cores per individual coarse bedform)



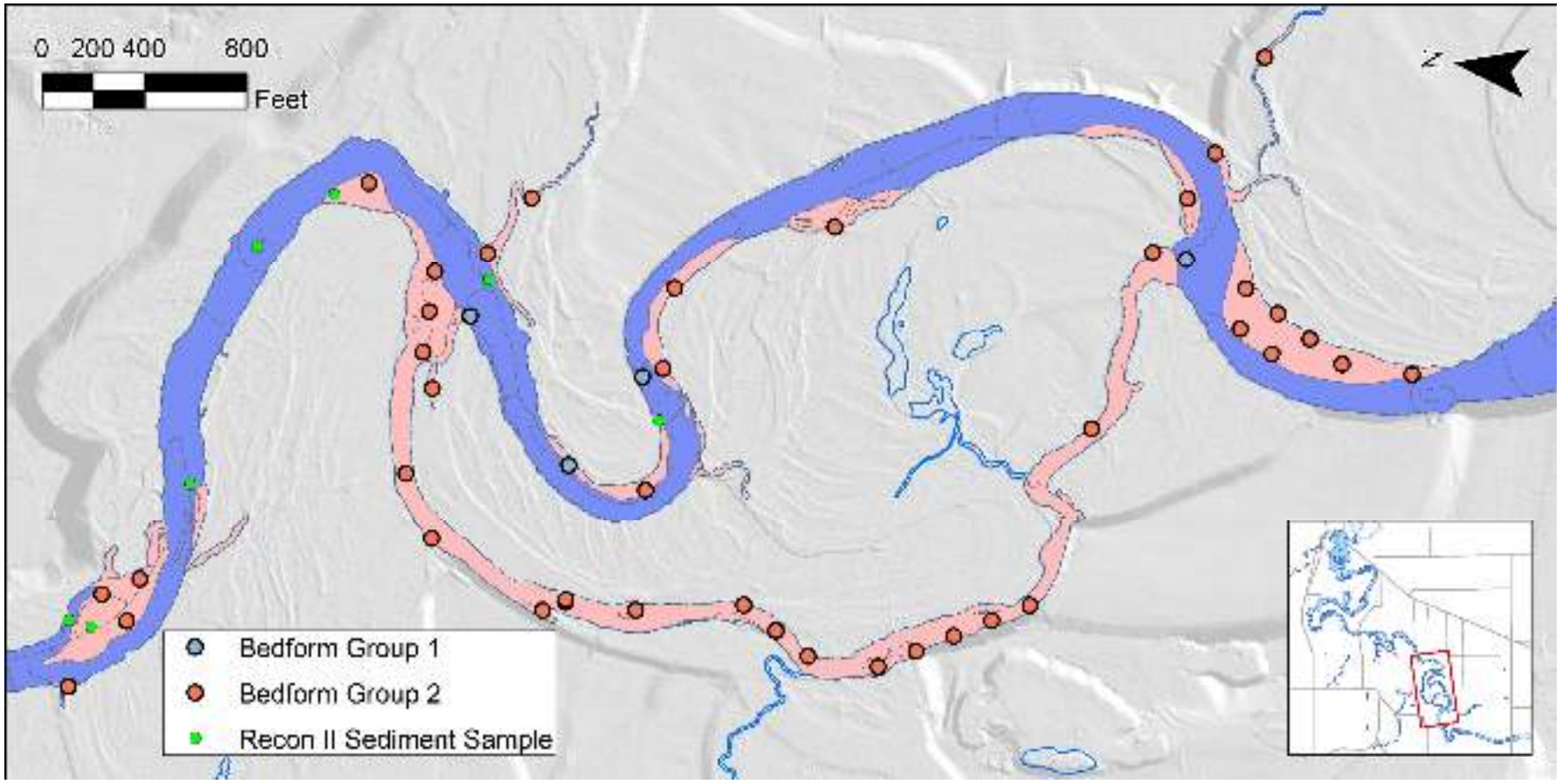
Phase I Sampling – Channelized Flow

- Stratified sampling using random origin
- 134 locations (new)
  - 18 in Bedform Group 1
  - 116 in Bedform Group 2
- Goal is to estimate SWAC

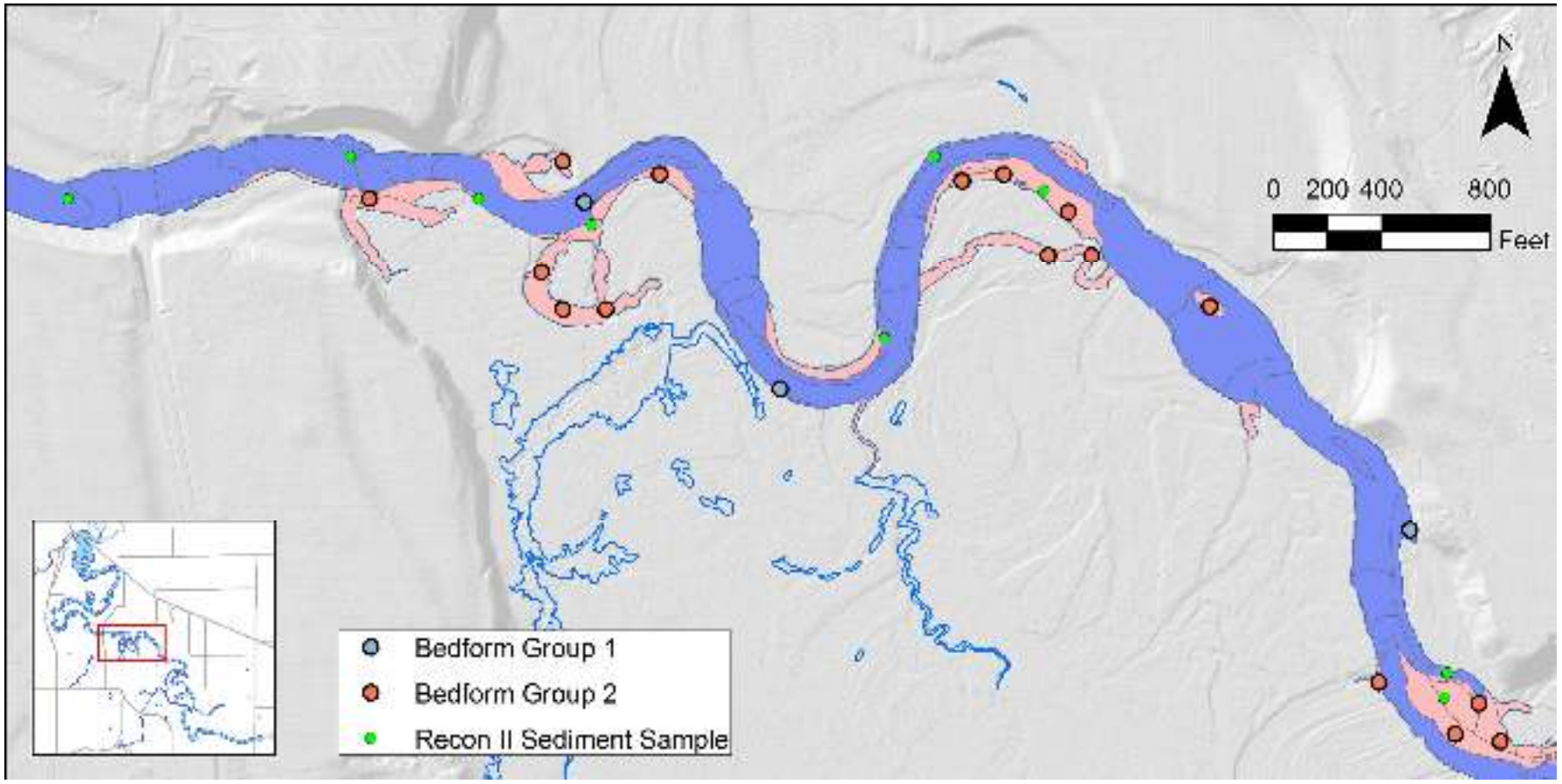
Phase I Sampling – Channelized Flow



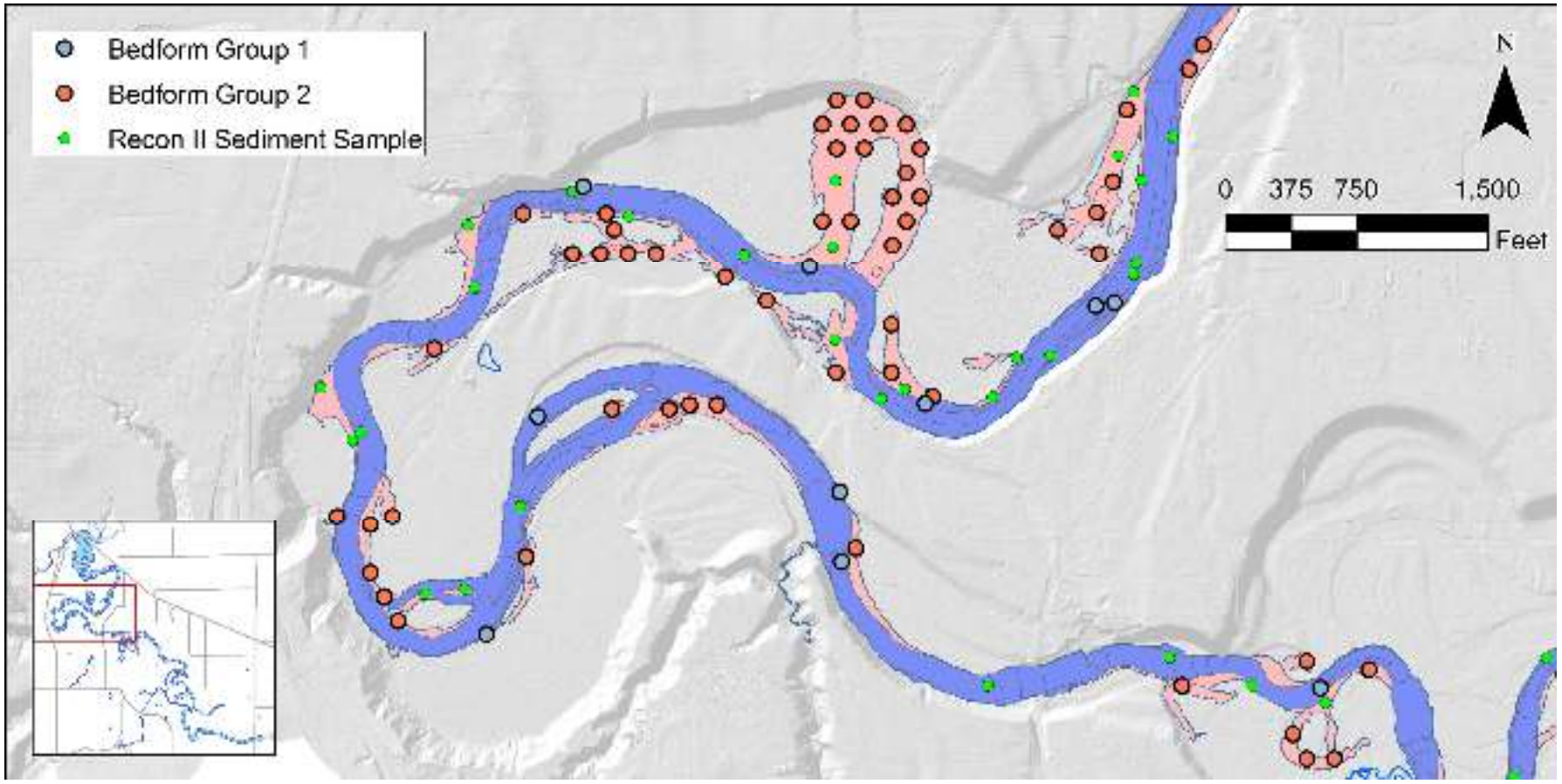
Phase I Sampling – Channelized Flow



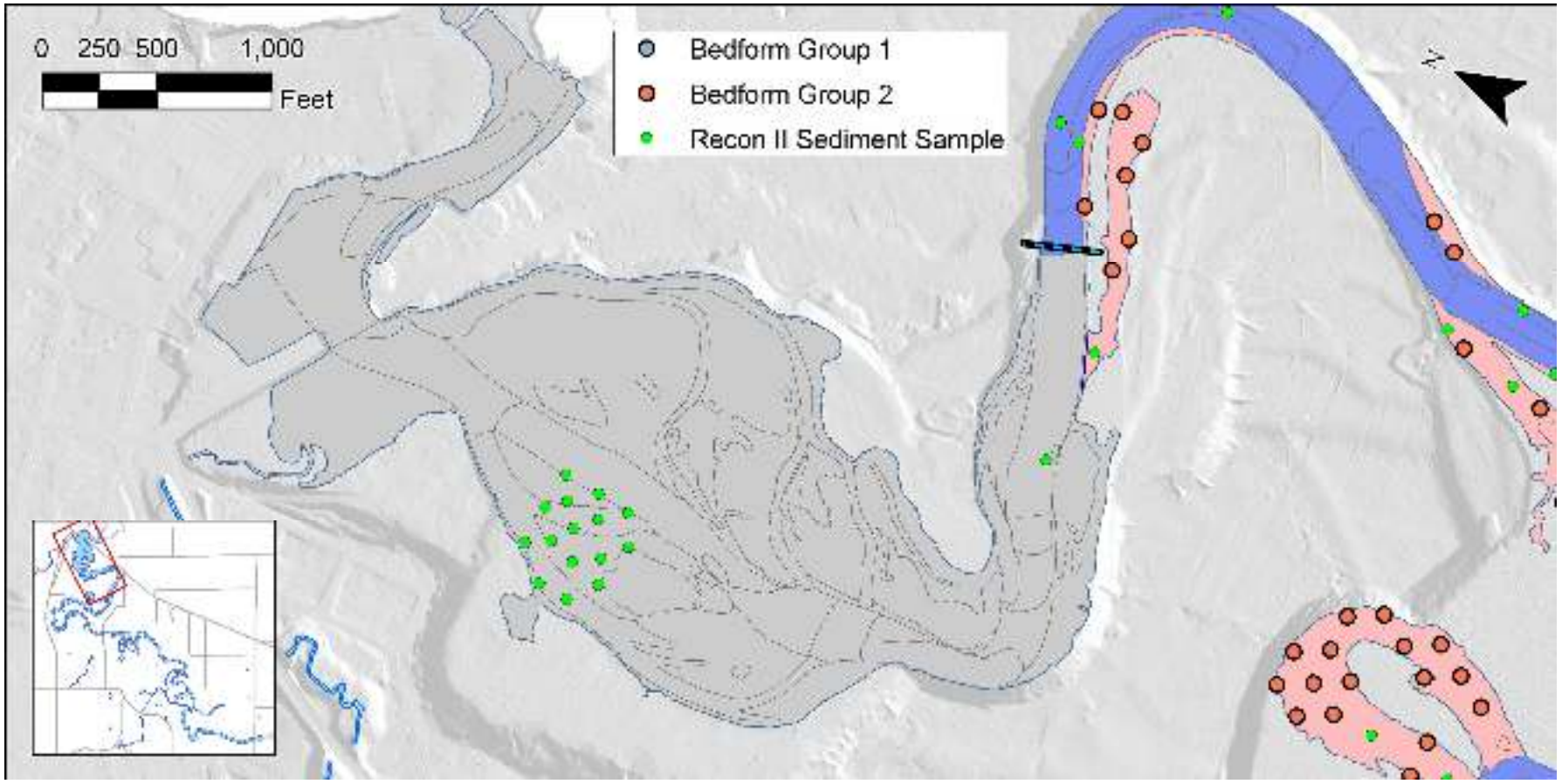
Phase I Sampling – Channelized Flow



Phase I Sampling – Channelized Flow



Phase I Sampling – Channelized Flow



Proposed Lab Analysis – Channelized Flow

All Phase I locations and intervals (134 locations):

- Total PCBs (Aroclor)

Select locations, surface interval only (76 locations):

- Total Organic Carbon (TOC)
- Percent Solids
- Gradation testing (sieve/hydrometer)
- Specific gravity

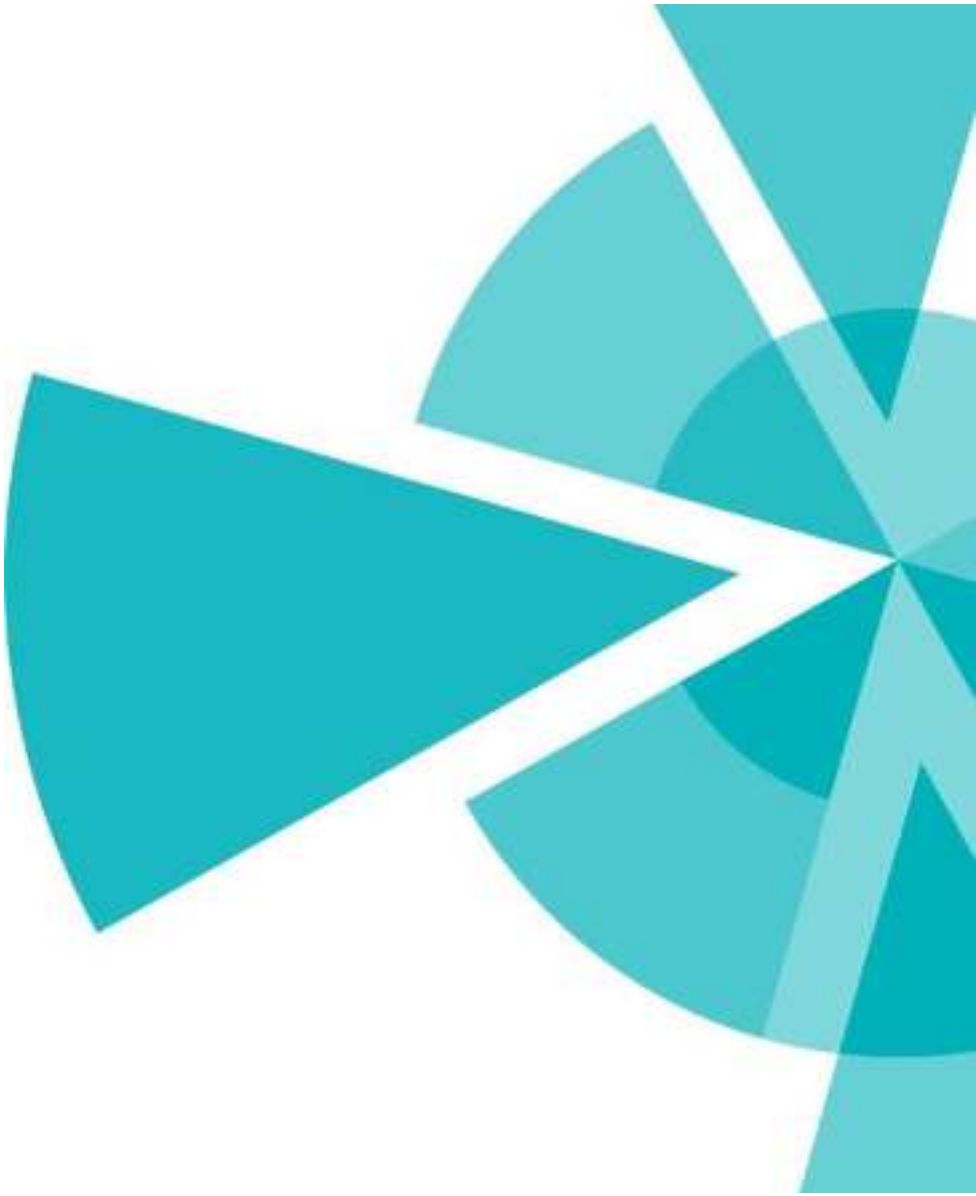
Select locations, two subsurface intervals (35 locations)

- Same as above

Floodplain Soils

CSM

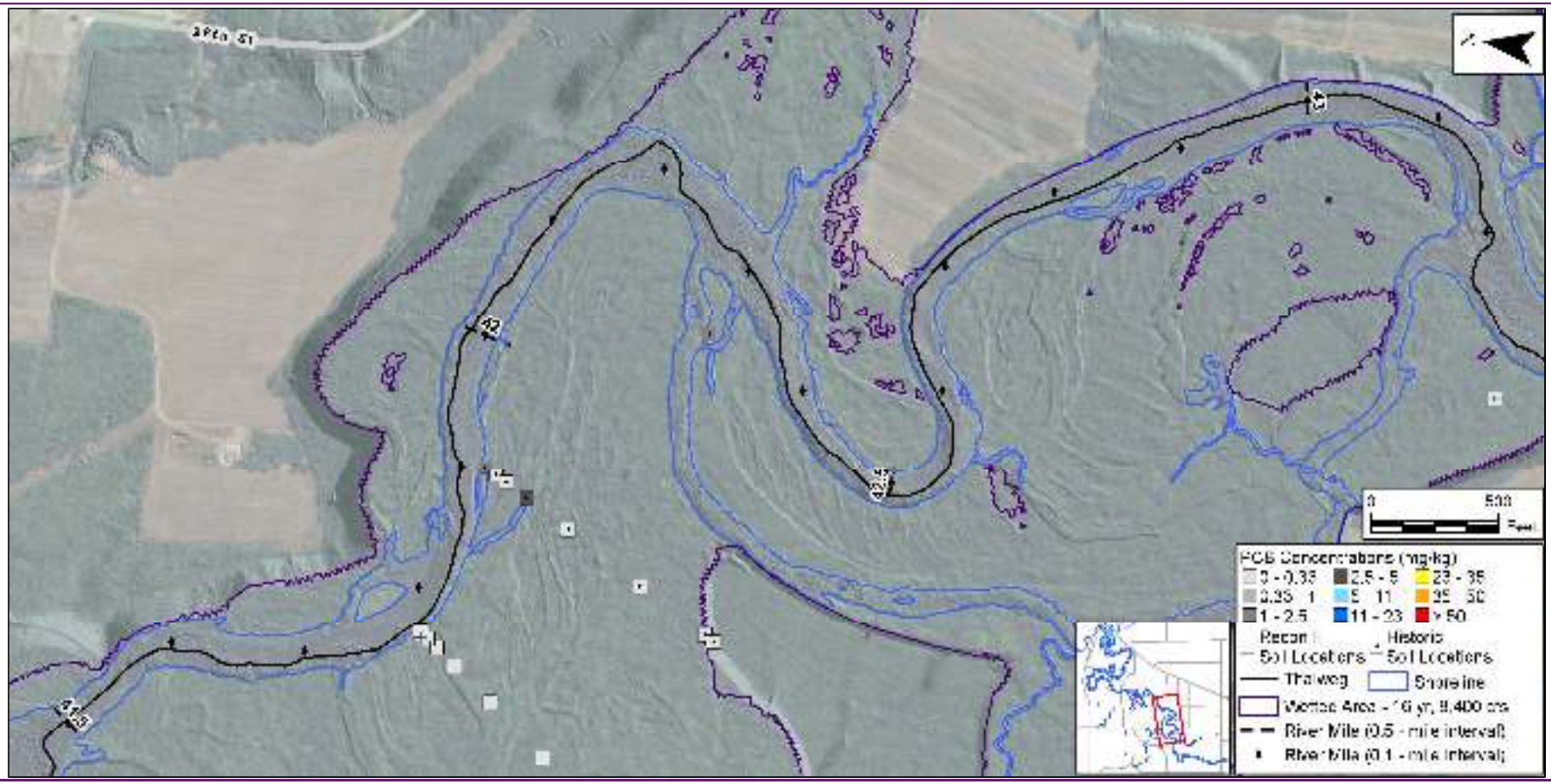
Recon I & II Data Evaluation



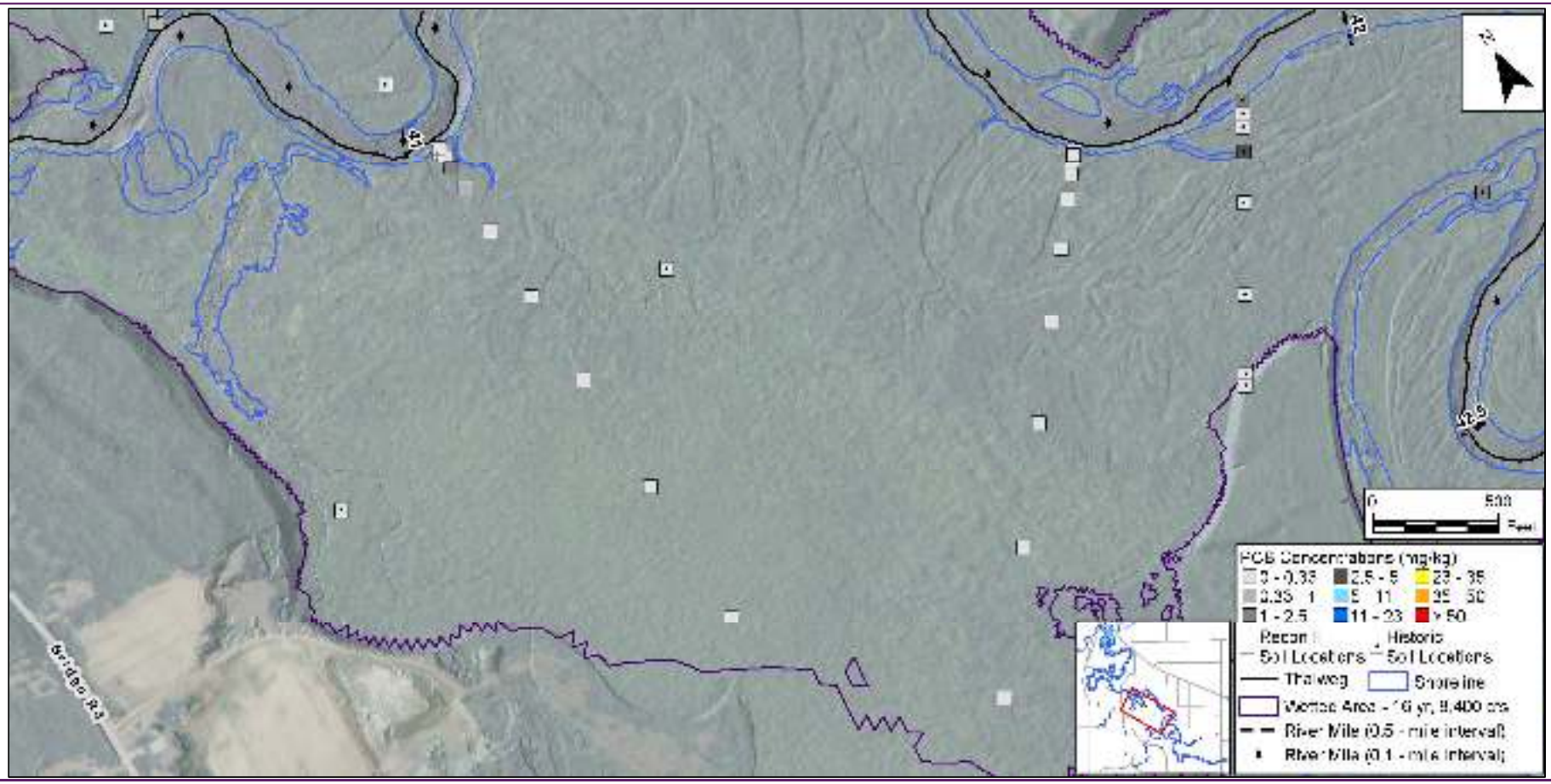
Area 5 Floodplain Soils CSM

- Flooding is only mechanism to transport PCBs to floodplain soils, not significantly influenced by impoundment
- "Historical floodplain soil data [from Area 1] suggest that flooding of the Kalamazoo River has not resulted in appreciable accumulation of PCBs in the natural floodplains in areas not influenced or inundated by the historical operations of dams (ARCADIS 2012)."
- Historical PCB samples in Area 5 have relatively low concentrations (<5 mg/kg)
- Study boundary developed using hydrodynamic model
  - Three >10-year events since historical loading (3rd one in Feb 2018)
  - Inundation relatively rare event
  - Vegetation acts as filter to reduce sediment transport to floodplains
  - Full extent of inundation may be due to runoff, tributaries, or groundwater

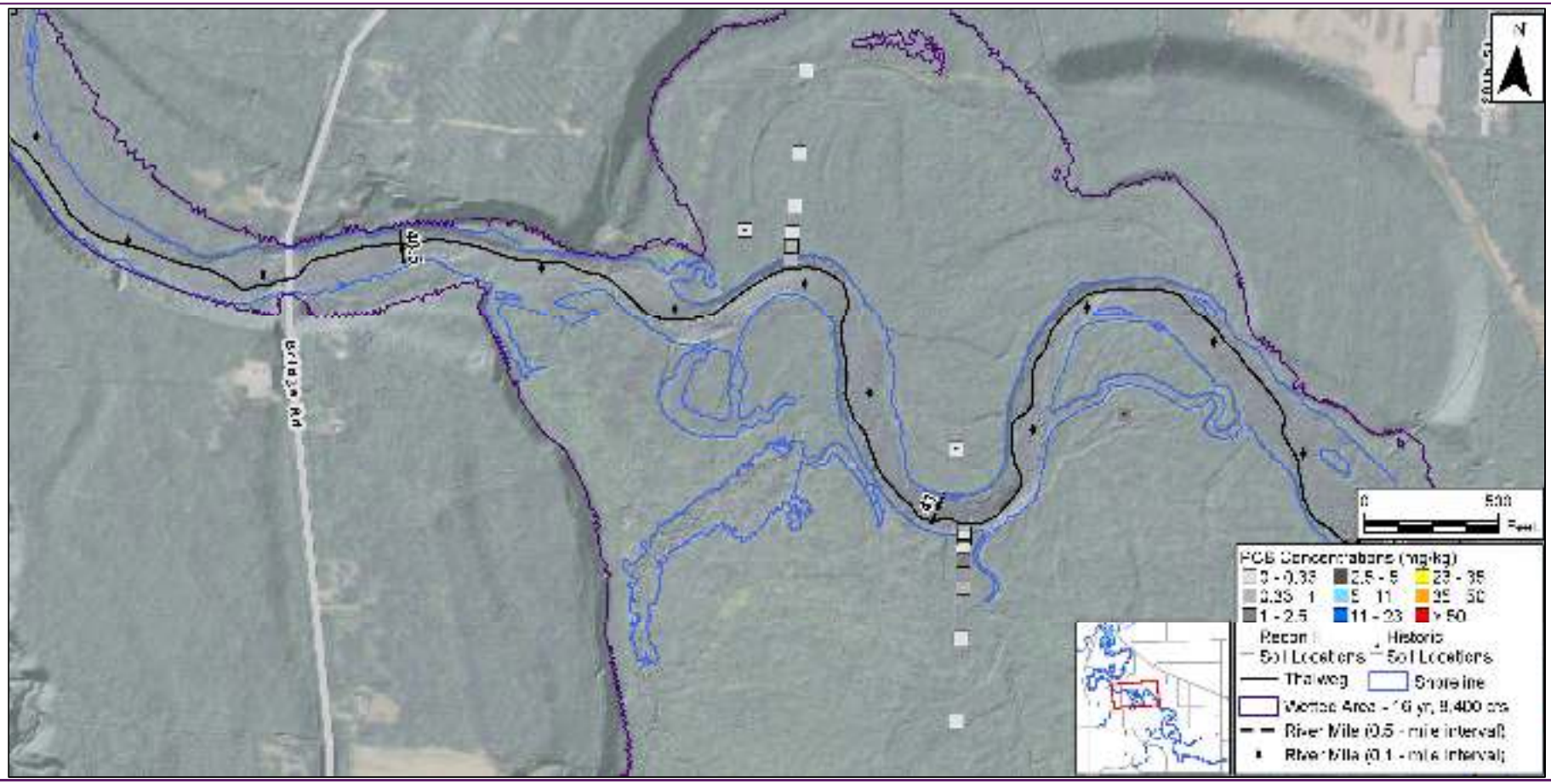
Historical and Recon II Max PCB Concentration in Any Standard Interval – Floodplain Soils



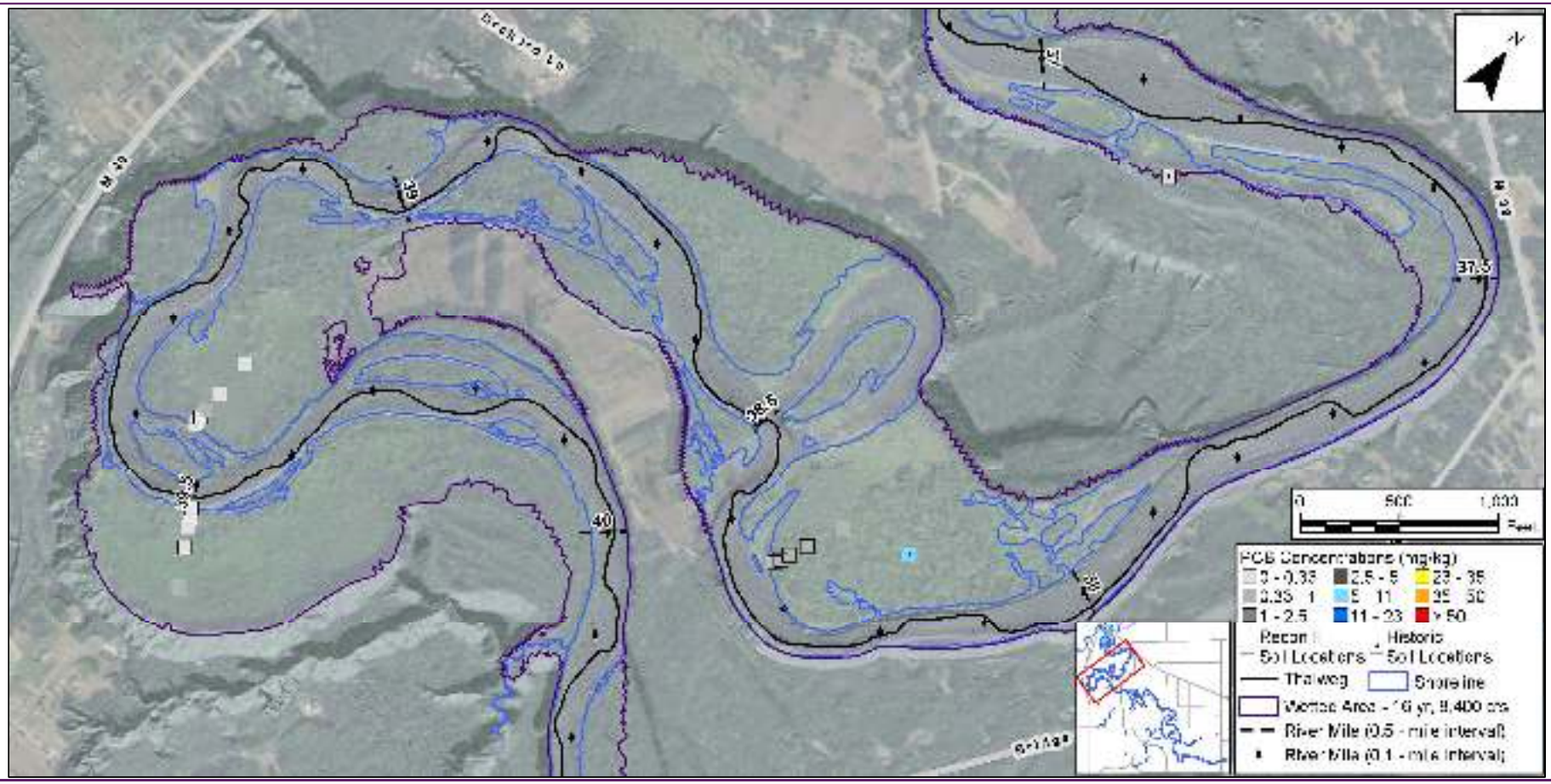
Historical and Recon II Max PCB Concentration in Any Standard Interval – Floodplain Soils



Historical and Recon II Max PCB Concentration in Any Standard Interval – Floodplain Soils



Historical and Recon II Max PCB Concentration in Any Standard Interval – Floodplain Soils

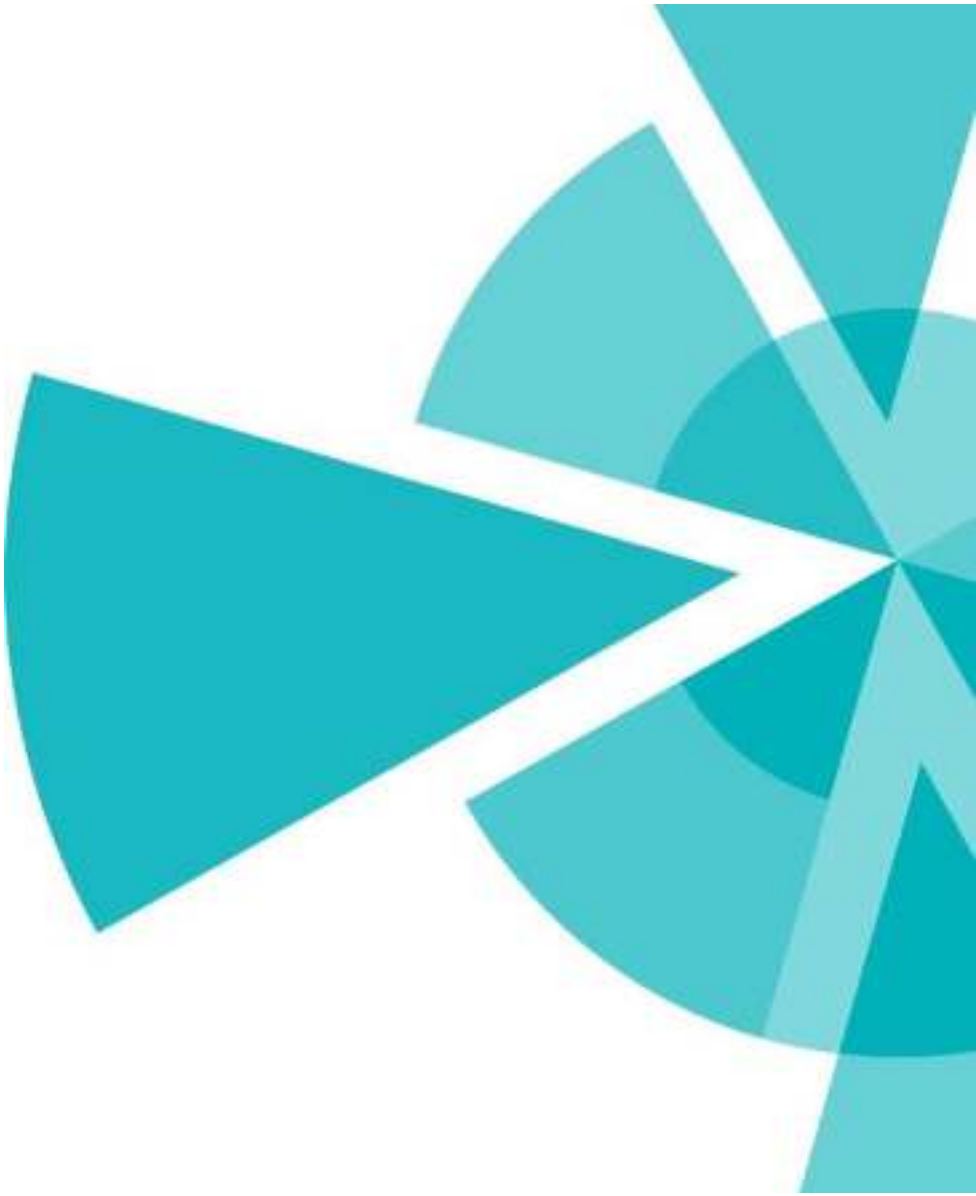


Potential Bank Soil Sampling Reserved for Phase II

- No evidence of widespread PCB contamination on floodplains to 16-Year return period extent
  - Historical samples have low concentrations
    - 44 of 52 samples w/ PCB conc. < 1 mg/kg
    - Maximum PCB conc. = 6.1 mg/kg
  - Recon II transects placed in lower elevation areas
    - 213 of 215 samples w/ PCB conc. < 1 mg/kg
    - Maximum PCB conc. = 1.1 mg/kg
- No mechanism to transport high concentration PCBs to floodplains
- Bank soil sampling in Phase II will be evaluated based on results of Phase I sediment sampling

MNR LOE Sampling

To be provided



Phase I Sampling Design Summary

- Impounded Lake
  - 105 cores
- Channelized Flow
  - 134 cores
    - 18 in Bedform Group 1
    - 116 in Bedform Group 2
- MNR LOE

Schedule

April 20	Draft FSP submitted to Work Group
Mid May	Work Group meeting/conference call to discuss draft FSP
Late May	Receipt of Draft FSP comments*
Early June	Work Group meeting/conference call to discuss comments and finalize FSP
July	Anticipated approval of FSP*
August 6-31	Phase I SRI field events

* Schedule dependent on receipt of comments and approval of FSP

Action Items